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RÉSUMÉ OF SOLAR OBSERVATIONS MADE AT THE ROYAL OBSERVATORY OF THE ROMAN COLLEGE DURING THE SECOND HALF OF 1896.

By P. TACCHINI.

I GIVE below a résumé of the solar observations made at the Royal Observatory of the Roman College during the second half of 1896. The following results have been obtained for the spots and faculæ:

1896	Number of days of observation	Relative Frequency		Relative Size		Number of spot groups per day
		of spots	of days without spots	of spots	of faculæ	
July	30	11.24	0.00	42.1	86.8	3.0
August	27	6.34	0.11	20.8	72.4	1.8
September	29	24.59	0.00	63.4	64.0	3.4
October	21	11.53	0.05	29.1	123.5	2.4
November	17	15.30	0.00	79.9	71.5	4.0
December	17	12.18	0.00	45.8	77.1	2.9

A point worthy of notice in this series of observations is the secondary minimum for the spots in the month of August, followed by a maximum, due largely to the appearance of the magnificent group visible from the 10th to the 22d of September. On September 16 this group was formed of sixteen spots and twenty-seven pores, and had an extent of 6′ parallel to the equator.

For the prominences we have obtained the following results:

1896	Number of days of observation	Prominences		
		Mean number	Mean height	Mean extent
July	30	4.26	36".2	1".8
August	24	4.00	34 .6	1 .1
September	26	3.77	34 .9	1 .2
October	14	6.93	38 .7	1 .6
November	9	5.56	39 .9	1 .9
December	9	3.78	39 .4	2 .0

The weather was very untavorable for spectroscopic observations during the fourth quarter, and especially during the last two months of the year. Even in August, when the weather is ordinarily most favorable, we frequently had a bad sky.

The minimum for the prominences occurred at the time of the spot maximum, and in comparison with the preceding series it may be said that the phenomena of the prominences have remained almost stationary.

Following are the results for the distribution in latitude of the different solar phenomena, calculated for each quarter:

1896 Latitude	Prominences				Faculæ				Spots			
	Third quarter		Fourth quarter		Third quarter		Fourth quarter		Third quarter		Fourth quarter	
90° + 80°	0.000		0.010									
80 + 70	0.000		0.010									
70 + 60	0.000		0.005									
60 + 50	0.042		0.047									
50 + 40	0.099	0.472	0.068	0.364	0.000							
40 + 30	0.127		0.073		0.000		0.013					
30 + 20	0.105		0.068		0.047	0.244	0.038	0.298	0.037			
20 + 10	0.062		0.052		0.090		0.120		0.182	0.345	0.075	0.200
10 + 0	0.034		0.031		0.107		0.127		0.126		0.125	
0 — 10	0.082		0.094		0.146		0.196		0.182		0.200	
10 — 20	0.130		0.120		0.276		0.253		0.382	0.655	0.600	0.800
20 — 30	0.141		0.162		0.223	0.756	0.190	0.702	0.021			
30 — 40	0.093		0.099		0.094		0.063					
40 — 50	0.065	0.528	0.099	0.636	0.017							
50 — 60	0.011		0.031									
60 — 70	0.006		0.016									
70 — 80	0.000		0.010									
80 — 90	0.000		0.005									

The frequency of each class of phenomena has increased in the southern zones. The prominences have been quite numerous from the equator to $\pm 50°$, as in the preceding six months. The faculæ have been confined within latitudes $\pm 40°$, and the spots within $\pm 30°$ during the third quarter and $\pm 20°$ during the fourth quarter. It must also be remarked that during the six months prominences have been seen in every zone, and very near to the poles.

The great extension in latitude and the wide zones of frequency of the prominences permit us to consider the solar corona to be more closely related to the prominences than to other solar phenomena. It follows that according to our observations the corona at the time of the last eclipse should have appeared low from the polar regions to the parallels of 60°, and clearly marked and much more extended from the equator up to $\pm 60°$, just as it is shown in such photographs and drawings as I have seen up to the present time. It therefore seems to me safe to say that the variations of the solar corona should be in accord with those of the prominences.

ROME, January 30, 1897.

OXYGEN IN THE SUN.

By Arthur Schuster.

In an important communication printed in the current number of the Astrophysical Journal (December 1896) Professors Runge and Paschen give strong evidence that one of the triplets of the spectrum, which I have called the "compound line spectrum" of oxygen, appears in the Sun. The question whether the lines of this spectrum coincide with dark solar lines was discussed by myself nearly twenty years ago (*Nature*, Dec. 20, 1877), and I then gave what at that time seemed to me to be the evidence in favor of its presence. But the resolving power used was inadequate, for the triplets were observed as single, their triplet nature being discovered later by Piazzi Smyth. As a matter of history I may quote the remarks made by this eminent spectroscopist on the solar coincidences with the compound line spectrum of oxygen. After referring to my own work on the subject he writes (*Trans. R. Soc. Edinburgh*, Vol. XXX, Part I) "In apparently the very place of the three fainter of the above described divided triplets there is a close double of peculiarly thin Fraunhofer lines depicted by Professor Ångström in his normal solar spectrum map; and in the place of the brightest of them, viz., Schuster's orange line, there is a triple of the same kind of ultra thin lines; and not one member of all those four groups has been claimed for any known element by the great Swedish physicist. Yet I am by no means satisfied that the degree of correspondence is conclusive; and can only hope that those who have the means will positively confront the new oxygen triples with the Sun itself, and inform us what they find." Nothing further was done on the subject until Runge and Paschen took the matter up, and gave additional weight to the probability of the presence of oxygen in the Sun. The coincidence they point out does not refer to any of the triplets which Piazzi Smyth mentions in the above quotation, but to one which lies in the red. The reason why I have referred to my

own contribution to the subject is not that I attach any weight to it (on the contrary, it is quite clear now that I could not with the dispersion I used institute any satisfactory comparison) but that in my letter to *Nature* to which reference has been made, I drew attention to one circumstance which seems to me to deserve the serious attention of those who have the necessary instruments at their disposal. This is the fact that Young gives in his list of chromospheric lines, observed at a height of 8300 feet, two lines having wave-lengths of 5435.4 and 5329.1, in Ångström's scale, the frequency of the first being given as 5, that of the second as 6. These lines are sufficiently near two of the oxygen triplets to make it desirable to ascertain their wave-lengths more closely, and especially to determine whether the chromospheric lines are not in reality close triplets. Without knowing that Runge and Paschen were engaged on this question I recently examined the oxygen spectrum with a Rowland concave grating in order to determine the wave-lengths more accurately. The wave-lengths for the more refrangible of the above triplets which I have obtained are on Rowland's scale

5330.793 5329.827 5329.293

I do not however wish to consider these numbers as final, as they are only the result of one series of measurements. There are two lines on Rowland's list (5329.329, 5329.975), which are very near the two strongest components of the triplet, but they are assigned to chromium, and if the oxygen lines are really in the Sun they would probably be hidden by these chromium lines. Rowland also gives a weak line corresponding to the weakest and least refrangible component of the triplet, 5330.748. So far then as this triplet is concerned the solar coincidence can neither be affirmed nor denied, but if the chromospheric line is really triple and in agreement with the members given, the presence of oxygen in the Sun would be proved beyond doubt. In view of the great importance of this subject in all problems referring to the constitution of the Sun, I may perhaps be allowed to urge the full investigation of this question on those who are working under sufficiently pure atmospheric conditions.

MANCHESTER, January 31, 1897.

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO.

I. SELECTION OF THE SITE.

By GEORGE E. HALE.

INTRODUCTION.

WHEN The University of Chicago commenced its work in the autumn of 1892 it was but poorly equipped for investigation in astronomy and astrophysics. The twelve-inch telescope and other apparatus of the Kenwood Observatory, though admirably adapted for certain kinds of astrophysical research, were useless in many fields of investigation which The University desired to enter. It was consequently felt that an effort should be made to provide The University with an observatory of the first class, equipped with facilities for observational and experimental work in all branches of astronomy and astrophysics.

In September, 1892, Mr. Charles T. Yerkes of Chicago, a gentleman widely known for his liberal encouragement of art, offered to purchase for The University of Chicago a pair of disks of optical glass 42 inches in diameter, by Mantois of Paris, which were then in the workshop of Mr. Alvan G. Clark at Cambridgeport, Mass. An opportunity to purchase such large and perfect disks is naturally a most exceptional one, arising in this instance from certain complications, which prevented an institution in southern California from carrying out its plan of establishing a large telescope in the vicinity of Pasadena. Mr. Yerkes' generous offer to The University, which included the assumption of the entire cost of building an equatorial refractor of forty inches aperture and housing it in a suitable observatory, was received with great satisfaction and accepted immediately. After the object-glass had been ordered from Mr. Clark, and a contract for the equatorial mounting had been made with Messrs. Warner and Swasey, the question of selecting a suitable site for the Observatory was taken up for consideration.

CONSIDERATIONS REGARDING THE CHOICE OF A SITE FOR AN ASTRONOMICAL OBSERVATORY.

In choosing an observatory site both general and special hindrances to observational work must be given consideration. In general, it is desirable to avoid localities where the mean annual cloudiness is high, or where much difficulty is likely to be experienced from wind, dust, or dew. The special requirements of the particular observations comprised in the Observatory's plan of work should next receive attention. In the following table, which has been prepared with the assistance of Professors Barnard and Wadsworth, I have indicated by the letters *A*, *B*, and *C* the approximate degree of excellence required in the "seeing," transparency of the atmosphere, blackness of the sky, and steadiness of the instruments, for various classes of astronomical and astrophysical work. In each case *A* indicates that the particular condition to which it refers should be the very best possible; *B*, that it should be fair to good; *C*, that it need be only fair, or may even be distinctly bad without materially affecting the quality of the work. Ordinarily the letters in the fourth column refer to the required degree of steadiness of the telescope or principal observing instrument. When a second accented letter is given it refers to the conditions required for a galvanometer or other similar apparatus. On account of the dependence of the blackness of the sky upon the transparency of the atmosphere, columns two and three might ordinarily be united. But the presence of fine dust in the atmosphere, while it increases the brightness of the sky to the eye, has little effect upon its transparency for the longer waves. Thus the conditions may frequently differ for spectroscopic work in the less refrangible region.

This grouping of familiar facts may be of service in emphasizing the diversity of conditions under which various classes of astronomical and astrophysical observations can be successfully made. It is evident that if the work of an observatory be chosen so as to harmonize with its environment, many results of great value may be obtained in localities which would generally be regarded as unfavorable. In the heart of a smoky city,

	Seeing	Transparency of atmosphere	Blackness of sky	Steadiness of instrument
STARS.				
Micrometric observations of double stars	A	B	B	A
Meridian observations:				
With meridian circle	A	C	C	A
With transit (time determinations)	B	C	C	B
Photography:				
With long focus telescope	A	B	B	A
With short focus telescope	B to C	A	A	B
Spectroscopy	A to B	B	B to C	B
Spectrography	B	B	B to C	B
Photometry:				
Absolute measures	B	A	A	B
Differential measures	B	B	B	B
NEBULÆ.				
Discovery	B	A	A	C
Micrometric measures	B	A	A	A to B
Photography:				
With long focus telescope	B	A	A	A
With short focus telescope	C	A	A	B
Spectroscopy and spectrography	C	B	B	B
Photometry:				
Absolute measures	B to C	A	A	B
Differential measures	B to C	B	B	B
MOON, BRIGHT PLANETS AND BRIGHT SATELLITES.				
Micrometric measures	A	C	C	A
Meridian observations	B	B	B	A
Photography	A	B	B	A to B
Spectroscopy and spectrography:				
Of general light	C	B to C	B to C	B
Of details	A to B	B to C	B to C	A to B
Photometry:				
Absolute measures	B	A	A	B
Differential measures	B	B	B	B
Observations of details	A	C	C	A to B
ASTEROIDS, FAINT PLANETS, AND FAINT SATELLITES.				
Discovery	A to B	A	A	A to B
Micrometric measures	A	B	B	A
Photography	A to B	A	A	A to B
Spectroscopy and spectrography	B	A	A to B	B
Photometry:				
Absolute measures	B	A	A	B
Differential measures	B	B	B	B
Observations of details	A	A to B	A to B	B
COMETS.				
Discovery	B to C	A	A	C
Micrometric measures	B	B	B	A to B
Photography	B to C	A	A	B
Spectroscopy and spectrography	C	B	B	B to C

	Seeing	Transparency of atmosphere	Blackness of sky	Steadiness of instrument
COMETS.				
Photometry:				
Absolute measures	C	A	A	B
Differential measures	C	B to C	B to C	B
SUN.				
Photosphere.				
Micrometric measures, visual and photographic observations of structure	A	C	C	A to B
Meridian observations	A	C	B	A
Photography, for measurement	A to B	B	B	A to B
Spectroscopy and spectrography:				
Of general light	C	C	C	B
Of details	A to B	C	C	A to B
Photometry of general light:				
Absolute measures	C	A	A	C
Differential measures	C	B to C	B to C	C
Heat radiation with thermopile, bolometer, or radio-micrometer:				
Absolute measures	C	A	A	CA
Differential measures	C	B to C	B to C	CA
Sun-Spots and Faculæ.				
Micrometric measures and visual observations of structure	A	C	C	A to B
Photography:				
Large scale, for details	A	C	C	B
Small scale, for positions	B	C	C	B to C
Of faculæ, with spectroheliograph	B	B	B	A to B
Spectroscopy and spectrography	B	B	B	B
Photometry:				
Absolute measures	B	A	A	B
Differential measures	B	B to C	B to C	B
Heat radiations, with thermopile, bolometer, or radio-micrometer:				
Absolute measures	B	A	A	BA
Differential measures	B	B	B	BA
Heat measures in spectrum	C	A to B	C	CA
Chromosphere and Prominences.				
Micrometric measures and observations of structure:				
Visual, with spectroscope	A	B	A	A to B
Photographic, with spectroheliograph	A to B	A	A	A to B
Spectroscopy and spectrography:				
Of prominences	B	A to B	A	B
Of chromosphere	A	A to B	A	A to B

illuminated by electric lights, where the sky is bright both day and night, delicate observations of chromospheric details, faint nebulæ and comets could not be advantageously made, nor could long exposure photographs of stars be taken. But even under such circumstances the staff of an observatory need not be idle. Observations of planets, satellites and double stars, spectroscopic studies of the stars, the solar photosphere, spots and faculæ, could be prosecuted, in most cases without serious hindrance from the surroundings. In fact, it would appear that certain observations could be made to the very best advantage under just such conditions, for the most successful existing records of the detailed structure of the solar photosphere and spots were obtained by Professor Langley at the Allegheny Observatory, in the midst of one of the smokiest districts of the United States. It is, indeed, a well-known fact that the presence in the atmosphere of a dense veil of smoke or haze is frequently accompanied by the most perfect seeing. It may be added that a very large proportion of Professor Burnham's double star discoveries and measures were made in Chicago, beginning with a six-inch telescope and concluding with the Dearborn refractor of 18½ inches aperture.

But while such considerations must affect existing institutions in their choice of work, the center of a city would certainly not be selected as the site of an observatory equipped for research in fields other than those just enumerated. Nor, in general, would a mountain peak. For notwithstanding a widespread impression to the contrary, the excellent atmospheric conditions enjoyed at the Lick Observatory do not seem to be common to all mountain summits.[1] So far as Professor Keeler and I could judge from observations made during our two weeks' stay on the summit of Pike's Peak (14,147 feet) in 1893, this would be an altogether unsuitable site for an observatory.[2] In 1894 I spent

[1] See Professor Holden's interesting memoir on "Mountain Observatories in America and Europe" (Smithsonian Miscellaneous Collections, No. 1035), which has come into my hands since this article was put in type.

[2] *A. and A.*, **13**, 679, 1894.

a week with Professor Riccò at the Observatory on Mt. Etna (9800 feet). Here the atmospheric conditions are affected by the neighborhood of the great crater, when the wind blows the heated air and sulphurous fumes toward the east. But with the wind in other quarters the seeing at night is sometimes very fine. However, the air currents rising from the heated mountain slopes soon after sunrise spoil the seeing, so that solar observations must be made when the Sun is hardly out of the haze which enshrouds the Calabrian coasts.[1] Professor Swift considers the seeing by no means good at the Mt. Lowe Observatory in southern California. At the Pic du Midi Observatory (9590 feet) MM. Thollon and Trépied[2] found the seeing in 1883 to be good at night, excellent shortly after sunrise while the Sun was still low, and very bad during the rest of the day. At Mt. Hamilton the day seeing is ordinarily bad,[3] but at night the atmospheric conditions appear to be unsurpassed. In general it may be said that while mountain observatories frequently enjoy the advantage of a blue sky during the day, they ordinarily suffer the disadvantage of poor seeing after the early morning hours. In some cases, as at the Lick Observatory, the seeing by night is excellent. In other cases it is worse than that found at lower levels.

It would appear that the best seeing should be found on an extensive plateau. The conditions for solar work would probably be best if the plateau were covered with a dense forest, shielding the surface of the earth from the direct rays of the Sun, and greatly reducing the radiation of heat from the soil.

SELECTION OF THE SITE OF THE YERKES OBSERVATORY.

The principal investigations to be made at the Yerkes Observatory, as outlined in the plan of work drawn up by the writer in 1892,[4] are intended to include solar observations, compris-

[1] *Ibid.*, p. 685.

[2] *C. R.*, **97**, 834, 1883.

[3] A recently published photograph of a Sun-spot made at the Lick Observatory seems to indicate that the day seeing is sometimes good. (*Pub. A. S. P.*, **9**, No. 54, 1897.)

[4] *A. and A.*, **11**, 791, 1892.

ing visual and photographic studies of the structure of the photosphere, spots and faculæ, photography of the faculæ, chromosphere and prominences with the spectroheliograph, spectroscopic observations, both visual and photographic, of all classes of solar phenomena, and bolometric and photometric investigations of various kinds; micrometric observations of double stars, nebulæ, planets, satellites, comets, etc.; photography of the Milky Way, stars, nebulæ, etc.; researches in stellar spectroscopy; meridian observations;[1] laboratory work of various kinds, principally with the spectroscope, bolometer and refractometer.[2] It is evident that in these various classes of work the greater part do not require very good seeing; but on account of the importance of the double star observations, and those of planets, satellites, the structure of the solar photosphere, etc., it was eminently desirable to choose a site at which the seeing would

[1] For the present to be confined mainly to time determinations.

[2] To form an idea of the minimum average conditions of seeing, transparency and blackness of the sky, and steadiness of the instruments permissible at a given observatory, the amount of time devoted to each class of work may be taken to indicate roughly the influence which the conditions required for these observations will have in deducing the average. It is practically impossible to determine the *value* of one class of work as compared with another, and a time basis, therefore, seems to be the only one that can be used. Times having been assigned in this way, as illustrated in the following example for the Yerkes Observatory, the averages may be taken at once. Such averages, while perhaps of no great value, at least indicate in a general way the nature of the conditions required. If, for example, the result *B* is obtained for the required average seeing, this of course does not mean that a site having an average seeing *A* would not offer greater advantages, but simply that with this minimum value the greater part of the observatory's work could be done without appreciable hindrance from atmospheric disturbance. It should be noted that, if few observations requiring seeing *A* are to be made, the difficulty of choosing a suitable site will be greatly decreased, for at most places good seeing is at least occasionally found.

Rough estimates of the relative amounts of time to be devoted each week at the Yerkes Observatory to the various classes of observations give: solar observations (three telescopes) 12; double stars (one telescope) 2; planets, satellites, comets, etc. (two telescopes) 5; stellar photography (portrait lens) 2; stellar spectrography (one telescope) 3; time service (transit) 1. Subdividing these classes of work still further, taking the corresponding data from the table, applying the proper times in place of weights and averaging, we have for the required minimum average conditions: Seeing, *B*. Transparency of atmosphere, *B*. Blackness of sky, *B*. Steadiness of instruments, *A* to *B*.

be the best attainable both by night and by day. Some of the other researches demand a dark sky and great transparency of the atmosphere, while for still others the principal requisite is complete protection of the instruments from vibrations of any kind. If there had been absolute freedom of choice, a site combining the excellent conditions for night work enjoyed at Mt. Hamilton with the good day seeing existing elsewhere would have been sought far and wide, without regard to geographical boundaries.

The practical choice of the site was materially influenced by the location of The University of Chicago. It was clearly understood by the members of The University Board of Trustees that if the Observatory were established upon The University campus there would be no possibility of entering successfully many of these important fields of investigation, and that a site must consequently be found outside the city of Chicago. At the same time the opinion was general that the Observatory could not be placed at a distance much greater than 100 miles from the city, without materially affecting its value as one of the departments of The University. There is no reason to suppose that the atmospheric conditions which prevail within a circle of this radius, with its center at Chicago, are surpassed by those existing at any point within a concentric circle having a radius of at least 500, perhaps even 1000 miles. Except in the case of the Lick Observatory,[1] which is about eighty miles by railway and carriage road from the University of California, all university observatories are located within a few miles of the other buildings of the institution. Harvard University has established a permanent observatory in Peru, but the principal observatory of the University is in Cambridge. If a university wishes to avail itself of the peculiar conditions existing in remote regions, it may do so by sending out expeditions or establishing branch observatories. It was believed that, in general, the principal observatory would be most advantageously situated if at no

[1] The site on Mt. Hamilton was selected before the Observatory entered into its present relationship with the University of California.

very great distance from the research laboratories of other departments.

As soon as it became generally known that the Yerkes Observatory was to be established outside the city of Chicago, numerous offers of land were made and other inducements were held out by individuals and by towns in various parts of the country. The offers included tracts of land in or near the towns of Morgan Park, Tracy, Highland Park, Downer's Grove, Hinsdale, Mt. Pleasant, Western Springs, La Grange, Glen Ellyn, Elmhurst, Elgin, Rockford, Peoria, Aurora, Waukegan, Belvidere, Sycamore, Marengo, Lena, Kankakee, Warren, Oregon, Princeton, Dixon, and Freeport in the state of Illinois; Lake Geneva in Wisconsin, and Pasadena in California. In company with a committee of the Board of Trustees the writer visited many of these places, and inspected the proffered sites. It soon became evident that the various tracts of land could be roughly classified as follows: (1) those in the suburbs of Chicago or other manufacturing cities; (2) those beyond the immediate suburbs, but situated at points where factories were likely to be established; (3) those situated where factories did not then exist, and were not likely to be established, near the shore of Lake Michigan; (4) those situated where factories did not then exist, and were not likely to be established, away from the vicinity of Lake Michigan. In order to assist in forming a correct estimate of the effect of smoke, electric lights, heated air, the jar produced by passing trains, and the neighborhood of a large body of water, upon the performance of the forty-inch telescope, I prepared a series of questions which were sent to Professors Barnard, Burnham, Hastings, Hough, Keeler, Langley, Newcomb, Pickering, and Young. The following abstracts of the replies received were embodied, with the conclusions which I have drawn from them, in a report presented to the Board of Trustees of The University of Chicago, on March 27, 1893. I may be permitted to express at this time the thanks of the Yerkes Observatory for these replies, as well as for the kindness of their authors in permitting them to be published.

QUESTION (1).

What do you consider the maximum distance at which a city like Chicago would appreciably affect observations with a forty-inch refractor?

ABSTRACTS OF REPLIES.[1]

I should regard a distance of ten miles as entirely outside the influence of the city dust and smoke.— *G. W. Hough.*

Evil effects of bodies of water, heated air and jar are entirely unnoticeable except in extreme cases. Smoke and electric lights more serious drawbacks, and city would produce injurious effect as far as these could be felt.— *Simon Newcomb.*

Depends in part on prevailing winds. Perhaps ten miles.— *S. P. Langley.*

Two miles if in direction of prevailing winds. Ten miles from borders of city if no prevailing wind. Should not be north of city.— *J. E. Keeler.*

Electric lights ten miles. Smoke perhaps five miles. Other causes one or two miles.— *E. C. Pickering.*

Twelve miles as good as sixty.— *S. W. Burnham.*

Uncertain. Perhaps ten miles, though electric lights might be felt further.— *C. A. Young.*

CONCLUSIONS.

A site not less than ten miles from the boundaries of the city should therefore be selected. Allowance must be also made for the future growth of the city.— *G. E. Hale.*

QUESTION (2).

What disadvantage arising from the proximity of Chicago would you consider most serious — smoke, electric lights, heated air, dust, jar or other?

ABSTRACTS OF REPLIES.

Smoke and electric lights.— *G. W. Hough.*

Smoke and electric lights decidedly. I do not suppose that heated air, dust or jar would produce any injurious effect.— *Simon Newcomb.*

Smoke and dust with irregular hot air currents.— *S. P. Langley.*

Smoke.— *J. E. Keeler.*

Smoke and electric lights.— *S. W. Burnham.*

Smoke and electric lights.— *C. A. Young.*

[1] Professor Barnard's replies were not received in time to incorporate them into the report.

Depends on kind of work. For faint objects electric lights would be chief hindrance.— *E. C. Pickering.*

CONCLUSION.

Sites in the vicinity of factories or electric lights must be avoided.— *G. E. Hale.*

QUESTION (3).

Do you consider that the proximity of Lake Michigan would affect the seeing in any way ?

ABSTRACTS OF REPLIES.

Cannot state definitely. I consider that the seeing at Evanston, on the shore of the lake, will compare favorably with that at any place in the eastern part of the United States.— *G. W. Hough.*

Do not know that any affect has ever been noticed.— *Simon Newcomb.*

Cannot say.— *S. P. Langley.*

Yes, probably.— *J. E. Keeler.*

Nothing is certainly known, but some bad effect would naturally be expected.— *E. C. Pickering.*

Would expect to have more nights with the best definition at points removed from the lake shore.— *S. W. Burnham.*

Presume it would, but would not venture to predict in what way. It might do as much good as harm taking the year through.— *C. A. Young.*

My experience goes to show the beneficial effect of a neighboring great body of water. Whether Lake Michigan could be considered of importance from this point of view I am unable to say.— *C. S. Hastings.*

QUESTION (4).

If so, would this effect differ in amount at points one hundred feet and twenty miles from the lake, respectively ?

ABSTRACTS OF REPLIES.

Ten miles inland annual temperature curve is a number of degrees higher in summer and lower in winter than in immediate vicinity of lake shore. Atmospheric conditions hence somewhat different, but cannot say whether better or worse.— *G. W. Hough.*

Sufficiently answered under (3).— *Simon Newcomb.*

If there is any disturbance I should think there would be a difference.— *S. P. Langley.*

At a distance of twenty miles it seems probable that the influence of the lake would cease to be felt.— *J. E. Keeler.*

Probably there would be a decided difference in favor of the remote station.— *E. C. Pickering.*

One would expect that greatest disturbance due to intermingling of air over lake and land would occur near the line joining land and water.— *S. W. Burnham.*

I should think it would. So far as *general* meteorological influence is concerned there would be little difference; but any special local effect of moisture in the air would be much more powerful within a mile of the lake than at a greater distance.— *C. A. Young.*

CONCLUSIONS.

Reports obtained from Professor Mark W. Harrington, Chief of the Weather Bureau, show the average annual cloudiness at three lake ports to be:—Chicago, 51 per cent., Milwaukee, 54 per cent., Grand Haven, 58 per cent. At a point forty-seven miles from Lake Michigan the average annual cloudiness, as learned from the same source, is only 47 per cent. Therefore, on account of the increased cloudiness, and the possibility of injury to the seeing arising from proximity to so large a body of water, no site within twenty miles of Lake Michigan should be selected.— *G. E. Hale.*

QUESTION (5).

Do you consider that the certainty of having an absolutely unobstructed sky over an angle of 180° would compensate for any disadvantage which might result from the close proximity of the lake?

ABSTRACTS OF REPLIES.

The lake horizon is of minor importance, as no useful observations can be made below an altitude of about fifteen degrees.— *G. W. Hough.*

Under no circumstances can good observations be made with a large instrument near the horizon.— *Simon Newcomb.*

I cannot answer as to this.— *S. P. Langley.*

No, I see no particular advantage in having a clear horizon.— *J. E Keeler.*

No, for observations near the horizon could seldom be required.— *E. C. Pickering.*

I do not consider a clear horizon all round to be a matter of much importance.— *S. W. Burnham.*

Certainly it would be a compensation to a certain extent. But if the proximity of the lake is seriously mischievous the extended view would not make up for it.— *C. A. Young.*

No.— *C. S. Hastings.*

CONCLUSIONS.

A site on the shore of the lake would have no advantage on account of the unobstructed easterly horizon. The certainty that no factories or buildings could ever be erected in the direction of the lake would be a distinct advantage, but not a sufficient one to compensate for the increased cloudiness as compared with an inland point.— *G. E. Hale.*

QUESTION (6).

At what maximum distance would an ordinary dwelling house interfere with observations with the forty-inch telescope?

ABSTRACTS OF REPLIES.

Single dwelling house at 200 feet distance would not sensibly affect the seeing, but it would not be admissable to surround the observatory with buildings at that minimum distance.— *G. W. Hough.*

Dwelling would not sensibly interfere at distance of 100 yards, unless telescope chanced to point directly over chimney.— *Simon Newcomb.*

An affair of prevailing winds. I should prefer to see none within one-half mile.— *S. P. Langley.*

At Mount Hamilton dwelling produces no injurious effect at distance of 100 yards.— *J. E. Keeler.*

One hundred yards.— *E. C. Pickering.*

An ordinary dwelling, or dwellings, as they would be placed with reference to this or any other observatory, would have no effect upon the atmospheric conditions.— *S. W. Burnham.*

Five hundred feet (?); am not sure.— *C. A. Young.*

CONCLUSIONS.

The observatory should stand in the center of a piece of land at least twenty acres in extent, from which all other buildings are excluded. To provide for future extensions it would be very desirable to devote not less than forty acres to the exclusive use of the observatory.— *G. E. Hale.*

QUESTION (7).

At what maximum distance would the jar of railroad trains interfere with observations with the forty-inch telescope?

ABSTRACTS OF REPLIES.

On sand or gravel a distance of 2000 feet from the railroad would be desirable. On clay or limestone jar may be sensible for a mile.— *G. W. Hough.*

Railway trains interfere with observations by reflection from mercury up to a distance of one and perhaps even one and one-half kilometers. Shaking of telescope would probably not be noticed at distance greater than 500 meters.— *Simon Newcomb.*

Depends on nature of underlying strata. With certain rock strata, at a very considerable distance, *e. g.*, several miles.— *S. P. Langley.*

It would be desirable to keep at least a quarter of a mile away from any railroad. Wind is much more serious.— *J. E. Keeler.*

Half a mile, but much depends upon the nature of the ground.— *E. C. Pickering.*

The passing by of railroad trains would be no objection to the use of this or any other telescope. A small puff of wind would produce more vibration than any number of railroads.— *S. W. Burnham.*

Quarter to half a mile, unless on a rocky ledge.— *C. A. Young.*

CONCLUSIONS.

The observatory should be situated at least half a mile from any railroad. Underlying strata of sand or gravel are most suitable. Rock should be avoided.—*G. E. Hale.*

ADDITIONAL REMARKS AND SUGGESTIONS.

To be of the greatest benefit to science the telescope should be mounted at some such point as Mt. Hamilton, California; Arequipa, Peru; or the Peak of Teneriffe.— *Simon Newcomb.*

In the absence of local knowledge the opinions I have expressed cannot be regarded as having great weight. They might be seriously modified by an examination of the peculiarities of the place.— *E. C. Pickering.*

I should select a point in a westerly direction from the city, and not more than twenty miles distant. Such a place can easily be found near some one of the numerous railroads, and be conveniently accessible at all times of day and night. This is a matter of much importance in the practical working of the observatory, and should not be overlooked.— *S. W. Burnham.*

The adoption of the conclusions arrived at by the writer after careful consideration of these replies led to the imme-

diate rejection of most of the places named. Further study finally resulted in the selection by the Board of Trustees of a tract of land on the shore of Lake Geneva, Wisconsin, which had been offered to The University by Mr. John Johnston, as the site of the future Observatory. Lake Geneva is a beautiful body of water, about eight miles long and one mile wide, situated in southern Wisconsin seventy-five miles by rail from Chicago.

The region is one where the mean annual cloudiness is low for this part of the United States, there is but little dust, and the nights of the best observing months are usually calm. The land presented to The University is a tract fifty-three acres in extent on the north shore of the lake, near its western end, and about one mile distant from the small town of Williams Bay, where a branch line of the Chicago and Northwestern Railroad terminates. The center of motion of the forty-inch telescope is about 240 feet above the level and 1800 feet from the shore of Lake Geneva,[1] and thirty-eight miles from the shore of Lake Michigan. The building is so situated in the midst of the grounds that it seems to be secure from any possible disturbance from without. Unlike most places in the vicinity of Chicago, the region about Lake Geneva offers no advantages to the manufacturer, and it is very improbable that the Observatory will ever be disturbed by factories in its vicinity. The lake is a favorite summer resort, and many Chicago people have country houses upon its shores. But these are for the most part well removed from each other and from the Observatory, and even if the present number were doubled or trebled the atmospheric conditions would not be appreciably affected. There are no electric lights nearer than Lake Geneva, a town of some 3000 inhabitants, about seven miles from the Observatory, at the eastern extremity of the lake. The surrounding country is a succession of woodland and cultivated fields, with the trees predominating in the near neighborhood of the Observatory. In general the site resembles that of the Astrophysical Observatory at Potsdam. The grounds of

[1] According to rather uncertain data the center of motion of the telescope is about 1200 feet above sea level.

the Observatory provide ample space for the erection of instruments in the open air. The soil is largely gravel, and as the nearest railroad is fully a mile and a half away there seems to be nothing to fear from vibrations of any kind.

Seemingly the only question which might arise regarding the suitability of this site for the purposes of the Yerkes Observatory depends upon its proximity to a small body of water. This question suggested itself to me the first time I visited the lake, and it was subsequently given very careful consideration. The opinions expressed by the various astronomers regarding the probable effect upon the seeing of so large a body of water as Lake Michigan showed that little or nothing was actually known from experience, although a very large number of observatories in all parts of the world are situated near oceans, lakes, and rivers. Such testimony made it seem extremely improbable that Lake Geneva, the area of which is about $\frac{1}{200}$ that of Lake Michigan, could appreciably affect the seeing. Two possible ways of determining the matter suggested themselves: (1) by means of a long series of observations extending through different seasons, to be made with a small telescope on the proposed site of the Observatory; (2) through an examination of observations made elsewhere with large instruments under as nearly as possible identical conditions. The first method was evidently one in which no great reliance could be placed, for when the seeing is good with a small telescope it by no means follows that it is good with a large one.[1] The second method seemed

[1] Observations were subsequently made in the summer months on the observatory site with a four-inch Clark refractor, and so far as could be judged with an instrument of this size, the seeing was very good on these occasions. In the few observations which it has been possible to make during the present winter, the neighborhood of the lake seems to have had no effect upon the seeing. Since its surface has been covered with a layer of ice nearly a foot thick, rendering it similar to the snow-covered fields in the vicinity, any possible effect due to a body of water differing in temperature from the air has been eliminated. Speaking generally, the seeing was perhaps rather better before the ice appeared, but the observations have necessarily been so few that no conclusions can be drawn. On many occasions the atmosphere has been exceedingly transparent, and I have several times observed the sky near the Sun to be as blue as it ever appeared during my visit to Mt. Etna.

much more likely to give reliable results, particularly on account of Professor Burnham's experience in observing double stars with the sixteen-inch telescope of the Washburn Observatory at Madison, Wis. The center of motion of this instrument is about 120 feet above the level of Lake Mendota, which is only about 650 feet away. In the immediate vicinity there are other small lakes, so that the Observatory is almost completely surrounded by water. Nevertheless Professor Burnham was never able to detect any inferiority of the seeing which could be attributed to the neighborhood of the lakes. He was strongly of the opinion that the site at Lake Geneva was quite as good as any to be found within one hundred miles of Chicago. On account of Professor Burnham's long experience as an observer and his previous study of the matter in connection with his selection of the site of the Lick Observatory, his opinion that the Yerkes Observatory might be established at Lake Geneva without fear of local atmospheric disturbance was accepted as final. The work of designing the buildings of the future Observatory was then undertaken.

YERKES OBSERVATORY,
February 1897.

(*To be continued.*)

PRELIMINARY TABLE OF SOLAR SPECTRUM WAVE-LENGTHS. XVIII.

By HENRY A. ROWLAND.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3562.549		0000	3567.517	Fe	1
3562.689		0000	3567.594		0000
3562.746		0000	3567.711		0000
3562.848		0000	3567.835		4
3563.065	Co	0 N	3567.881		2
3563.152		000	3568.083		00
3563.298		000 N	3568.147		0000
3563.542		000 N	3568.281		0000
3563.750		00	3568.387		00
3563.855		0000	3568.451		0000
3563.928		000 N	3568.587	Fe	3
3564.065		0000 N	3568.767		00
3564.264	Fe-Co	4	3568.968	Fe	3
3564.418		0000	3569.122	Fe	4
3564.537		0000	3569.281		0000
3564.664 } s	Ti	3	3569.371		0000
3564.705 }	Fe	2	3569.523	Co	5
3564.822		000	3569.649	Mn	4
3564.935		00	3569.761		0000
3565.075	Co	4	3569.873		0
3565.128		3	3569.958	Mn	2
3565.268		1 N	3570.060		000
3565.445		3 N	3570.183 } s	Mn	4
3565.535 s	Fe	20	3570.273 }	Fe	20
3565.735		4	3570.415 s		4
3565.855		000 N	3570.566		0000
3565.977		0	3570.660		0
3566.111	Ti	1	3570.736		0000
3566.227		000	3570.826		0000
3566.314		2 N	3571.000		0000
3566.454	Cr	0 N	3571.126		0
3566.522	Ni	10	3571.250	Pd	0000
3566.624		0	3571.374	Fe	3
3566.728		1	3571.546		00
3566.807		0000	3571.690		0000
3566.897		0000	3571.828		2
3566.984		0000	3571.913		000
3567.061		1	3572.014	Ni	6
3567.181	Fe	2	3572.155	Fe	5
3567.334		0000 N	3572.280		03

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3572.460		0000	3578.530	Fe	4
3572.617		4	3578.702		0
3572.712	-,Sc	6	3578.832	Cr	10
3572.890	Cr?	00	3578.978		000
3573.017		0000 N	3579.047	Co	0
3573.087		0000 N	3579.122		00
3573.207	Fe	1 N	3579.185		00
3573.320		0000	3579.268		0000 N
3573.417		0000	3579.508		000 N
3573.540	Fe	2	3579.648		0000
3573.650		0000	3579.702		1
3573.792	Ti	2	3579.812		0000
3573.874	Fe	3	3579.974		2
3573.975	Fe	3	3580.098		000 N
3574.050		2	3580.227		00
3574.135		0	3580.356		1 N
3574.174		0	3580.552		1
3574.297		0000	3580.682		1 N
3574.394	Ti	0	3580.898		0 N
3574.499		000	3581.067		5
3574.559	La	1	3581.184		1
3574.723		0000 N	3581.349 s	Fe	30
3574.944	Cr	0	3581.531		1
3575.106	Cr-Co	5	3581.617		0
3575.260	Fe	3	3581.805	Fe	2
3575.391	Fe	3	3581.957	Fe	2
3575.494	Fe	2	3582.081		1
3575.533	Co	2	3582.231		00
3575.699		000	3582.345	Fe	5
3575.904	Zr	00	3582.471		2
3576.118	Fe	4	3582.577		000
3576.296		0000	3582.711	Fe	2
3576.393		0000	3582.838	Fe	3
3576.469		4	3582.884		00
3576.527	-,Sc?	3	3583.017		0000
3576.739		0000	3583.104		000
3576.906	Fe	2	3583.244		0000
3577.003	Zr	1	3583.357		000
3577.099		0000	3583.481 s	Fe	5
3577.203		000	3583.581		0000
3577.299		000	3583.637		0000
3577.384	Co	1	3583.737		0000
3577.532		000	3583.837	-,C	3
3577.605		1	3584.051	-,C	3
3577.705		0000	3584.147		0000
3577.885		0000	3584.237		0000
3578.014	Mn	5	3584.397		0000
3578.138		0000	3584.457		000
3578.240	Co	1	3584.523		0000
3578.358	Ti	00	3584.616		0000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3584.660 s	Y	2	3590.803	Fe	00
3584.800	Fe	6	3590.976		0000 N
3584.940	Co	5	3591.149	Fe	1
3585.105	Fe	6	3591.283		0000
3585.214		000	3591.366		0000
3585.310	Co	5	3591.496	Fe	2
3585.479	Fe	7	3591.629	Fe	2
3585.658		2	3591.732		0000
3585.777		000 N	3591.885		0000 N
3585.859	Fe	6	3592.045		0000 N
3585.984 s [1]	C	0	3592.169	V?	2
3586.047 s	C	00	3592.348		0000
3586.157	Co	1	3592.412		000
3586.268	Fe	4	3592.508		0000
3586.390		000	3592.619	Fe	1
3586.494		00	3592.745		000
3586.624		0000	3592.819	Fe	3
3586.684	Mn	4	3592.935		0000
3586.890		3	3593.040	Y	0
3587.024		0	3593.158		0000
3587.130	Fe	8	3593.223		0
3587.286	Ti	2	3593.402		000
3587.370	Co	7	3593.481	Fe	3
3587.497		000	3593.636	Cr	9
3587.574	Fe	3	3593.835		000
3587.757	C	0000 N	3593.935		000
3587.899	Fe	5	3594.138		000 N
3588.084	Ni	6	3594.245		000
3588.263	C	000	3594.458		0000
3588.387		0	3594.528		0000
3588.466	C	00	3594.784	Fe	6
3588.563		0000	3595.017	Co	3
3588.675		3	3595.161		0000
3588.763	Fe	4	3595.256	Mn	1
3588.916	C	0000	3595.449	Fe, Ti	2
3589.065	Fe, C	2	3595.554		0000
3589.253	Fe	4	3595.681		0000 N
3589.363	C	0000	3595.824		000
3589.446	C	000	3596.012	Fe	1
3589.601	Fe	2	3596.195	Ti	4
3589.773		5	3596.346	Fe	1
3589.908		5 d?	3596.454		0000
3590.023	C	0000	3596.534		0000
3590.109	Mn, C	00	3596.651	Co	0
3590.235	Fe, C	1	3596.787		0000
3590.383		0000	3596.894		0000
3590.443		0000	3597.001		0000
3590.509 [2]	C	2 N	3597.189 s	Fe	5 d?
3590.609		2	3597.294		0000
3590.651		2	3597.394		0000Nd?

[1] Beginning of second head of carbon band.

[2] Beginning of first head of carbon band.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3597.541		0000	3603.719		2
3597.654		0000	3603.762		2
3597.854	Ni	8	3603.832		2
3597.994	Fe	00	3603.922	Ti	3
3598.121		0000	3603.972	Fe	4
3598.167		0000	3604.091		1
3598.324		0000 N	3604.259		0000 N
3598.414		1	3604.419	Ti	1
3598.611		0000 N	3604.519	Fe	2
3598.754		0000	3604.605		0000
3598.862	Ti, Fe	1	3604.699		0000
3598.953		0000	3604.843		1
3599.084	Fe?	2	3604.945		0000
3599.128	Fe?	2	3605.073		000
3599.287	Fe	2	3605.159		000
3599.523		000 N	3605.222		00
3599.686		0000	3605.341	Fe?	5
3599.774	Fe	3	3605.479 s	Cr	7
3599.906		0000	3605.615 } s	Fe	4
3599.973		0000	3605.669 }	Fe	4
3600.112		1	3605.832		0000 N
3600.313		0000 N	3606.059	Fe	1
3600.513		0000	3606.179		000
3600.596		0000 N	3606.272		0000
3600.733		0000	3606.391		0000
3600.880 s	Y	3	3606.518		0
3600.966		0000	3606.678	Fe	2
3601.060		0000	3606.751		1
3601.220		0000 N	3606.838 s	Fe	6
3601.340		000	3606.994	Ni	1
3601.426		0000	3607.144		0000
3601.500		0000 N	3607.264		0000
3601.570		000	3607.391	Zr	0000
3601.686		0000	3607.518		000
3601.806	Cr	0	3607.672	Mn	3
3601.930		0000	3607.764		0000
3602.060 s	Y	1	3607.911		0000 N
3602.210	Co	3	3608.004		000 N
3602.253	Fe	2	3608.111		0000
3602.559	Ni	4	3608.149		2
3602.611	Fe	3	3608.291	-,Fe	4 d?
3602.686	Fe	4	3608.458		000 N
3602.739		0000	3608.551		000
3602.849		000	3608.630	Mn	3
3602.912		0	3608.728		00 N
3603.019		0000	3608.778		000 N
3603.112		0000	3608.871		1 N
3603.238		1	3609.008 s	Fe	20
3603.354	Fe	5	3609.134		0 N
3603.579		0000	3609.244		0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3609.467	Ni	5d?	3615.462		0000
3609.611		2	3615.531	Co, Mn	00
3609.697	Pd	00	3615.669		0000 N
3609.853		0000 N	3615.802	Fe	3
3609.907		000 N	3615.949		0000
3610.017		0000 N	3616.100	Fe	0
3610.195		0 N	3616.294		2
3610.305	Fe, Ti	5	3616.357		1
3610.435	Mn	2	3616.465	Fe	1
3610.599	Cd?	4	3616.569		0000
3610.647	Ni	5	3616.710	Fe	4
3610.841	Fe	3	3616.866		0000 N
3610.970		0000	3617.016		0000 N
3611.083		0000 N	3617.149		0
3611.189 s	Y, Mg?	2	3617.243	Fe	1
3611.323		1	3617.315		0000
3611.443		000	3617.457	Fe	3
3611.598	Ni	0	3617.575	Mn	2
3611.697		00	3617.677		000
3611.862	Co,-	2	3617.855 } s	Ca?	1
3612.037	Zr	00	3617.934 }	Fe	6
3612.213 s	Fe	4	3618.098		2 N
3612.383		0000 N	3618.228		0000
3612.520		0000 N	3618.325		000
3612.657		000	3618.441	Ca?	3
3612.743		000	3618.532	Fe	3
3612.882	Ni	6d?	3618.661		00
3613.079	Fe, Cd	3	3618.753		1 N
3613.247		2	3618.919 s	Fe	20
3613.314	Fe	1 N	3619.061		0
3613.470		0000	3619.138		00 N
3613.587	Ti	2	3619.253		0
3613.739	Ti	2	3619.412	Mn	1
3613.857		0	3619.539	Ni	8
3613.947	-,Sc	4	3619.675		0 N
3614.019		3	3619.809		00
3614.090		0000	3619.915	Fe	2
3614.159		0000	3620.076		1
3614.257	Fe	2	3620.171		0
3614.446		0000 N	3620.295		0000
3614.549		0000	3620.387	Fe	2
3614.697	Fe	2	3620.578		0000
3614.789	Zr	0000	3620.609	Fe	3
3614.856	Fe	2	3620.758		0000 N
3614.922		2	3620.911		0000 N
3615.029		00	3621.018	Fe	1
3615.142		0000	3621.110	Y?	00
3615.222		0000	3621.244		3
3615.336	Fe	1	3621.340		2
			3621.400		0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3621.520		0000 N	3627.763		000
3621.612 s	Fe	6	3627.855		00
3621.740		0000	3627.953	Co	4
3621.864	Fe	2	3628.099		0000 N
3622.007		0000 N	3628.238	Fe	2
3622.147 s	Fe	6	3628.419		000 N
3622.297		0	3628.579		0000 N
3622.407		0000	3628.739		00
3622.577		0000 N	3628.847 s	Y, Mg?	2
3622.694		0000 N	3628.967	La	2
3622.794		000	3629.019		0000
3622.934		0000	3629.146		0000
3623.040		0000	3629.286		0000Nd?
3623.180		0000	3629.492		000 N
3623.234		0000	3629.652		0000 N
3623.362 s	Fe	5	3629.877	Mn	1
3623.460		0000	3630.045	Ni	1
3623.588 s	Fe	2	3630.164		1
3623.650		00	3630.252		0000
3623.750		0000	3630.374		0
3623.925	Mn, Fe	4	3630.492	Fe	4
3624.057		1	3630.618		0000
3624.204		2	3630.718		0000
3624.258	Ca	3	3630.798		0000
3624.447	Fe Co	3	3630.876		4
3624.600		0000 N	3630.918		3
3624.707		0000	3631.124	Ca	2
3624.873	Ni	4	3631.244	Fe	3
3624.979	Ti, Fe	5	3631.404	Co	1
3625.103	Co	1	3631.495	Ti?	0
3625.287	Fe	5	3631.605 s	Fe	15
3625.389		0000	3631.725		0
3625.506		0000 N	3631.850	Co	1
3625.641		1	3631.928		000 N
3625.766		0000 N	3632.098		2
3625.893		000	3632.193	Fe	3
3625.993		0000	3632.312		0
3626.073		0000	3632.438		00
3626.156		0000	3632.585		0000
3626.249	Ti	0	3632.700	Fe	3
3626.327	Fe	1	3632.832		0000
3626.526		0000 N	3632.979	Co, Cr, Zr	1
3626.633		0000 N	3633.123	Fe	4
3626.746		0000	3633.215		2
3626.877		2	3633.277	Y	2
3627.046		0000 N	3633.447		0000 N
3627.201	Fe	2	3633.651	Ti	00 Nd?
3627.309		000	3633.701		000
3627.499		000 N	3633.974	Fe	4
3627.596		000 N	3634.031		1

Wave-length	Substance	Intensity and Character
3634.144		0000 N
3634.337		3
3634.417		000
3634.471	Fe	3
3634.551		1
3634.611		00
3634.674		000
3634.757	Pd	0000
3634.849	Fe-Co	4
3635.004		0000
3635.091	Ni	3
3635.164		1
3635.224		0000
3635.336	Ti, Fe	2
3635.419		000
3635.491		00
3635.608 s	Ti, Fe	4
3635.791		000 N
3635.967		00
3636.034		0000
3636.184		0000
3636.305	Fe	3
3636.377	Fe	2
3636.624		1
3636.728	Cr	2
3636.802	Fe	2
3636.890	Co	2
3637.004		0000
3637.139		2
3637.197	Fe	1
3637.397	Fe	1
3637.456		0000
3637.583		0000
3637.693		00
3637.876	Fe	0
3638.011	Fe	4
3638.113		000
3638.196		0000
3638.242		1
3638.306		1
3638.383		1
3638.442 s	Fe	3
3638.610		0000
3638.743		0000
3638.910		0000
3639.043		000
3639.168	V	0
3639.270		0000
3639.423		1
3639.470		0000
3639.588	Co	2
3639.663	Pb	1
3639.833		0000
3639.943	Cr	2
3640.123		0000
3640.256		0000 N
3640.403		0000
3640.535 s	Cr-Fe	6
3640.783		000
3640.903		0000
3641.043		0000
3641.170		1
3641.366		0000 N
3641.473	Ti	4
3641.597	Mn, Cr	1
3641.784	Ni	1
3641.930	Co	0
3641.970	Cr	1
3642.102	Fe	00
3642.285		0000 N
3642.419		000 N
3642.536		000
3642.675		0000
3642.820	Ti	7
3642.912	Sc	2
3642.965		3
3643.109		0000
3643.262	Fe	2
3643.342	Co	1
3643.492		0000
3643.615		0000
3643.764	Fe	4
3643.867	Fe?	2
3643.949		3
3644.089		000
3644.212		0000 N
3644.289		0000 N
3644.455		0000 N
3644.555	Ti, Ca	5
3644.729		0
3644.833	Ti, Fe	1
3644.932	Fe	3
3645.117		0
3645.221	Fe	2
3645.325		0000
3645.429		3
3645.475	Sc?,-	3
3645.552	La	00
3645.636	Fe	3
3645.765		0000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3645.967	Fe	4	3652.691 s	Co	3
3646.074		0000	3652.820		0000Nd?
3646.128		0000	3653.023		0000
3646.236		00	3653.160		0000
3646.335	Ti	1	3653.260		0000
3646.491		0000 Nd?	3653.340		0000
3646.643		000	3653.492		1
3646.757		2	3653.637 s	Ti	5
3646.948		000 N	3653.799		0000
3646.976		00 N	3653.900	Fe	2
3647.128		2	3654.052	Cr	2
3647.234	Co	0	3654.119	Fe	2
3647.394		0000 Nd?	3654.266		0000 N
3647.561	Fe	4	3654.392		0000 N
3647.701		0	3654.526		0000
3647.808		0	3654.586	Co	00
3647.988 s	Fe	12	3654.738	Ti	2
3648.221	Co	0 N	3654.813	Fe	1
3648.367		0	3654.999	Hg?	0000
3648.461		00 N	3655.143	Fe	2
3648.669	Cr	0	3655.199		0000
3648.778		0000	3655.359		00
3648.898		0000	3655.495		1
3648.954		000	3655.609	Fe	3
3649.137	Cr	1	3655.719		0000
3649.234		0000	3655.801		3
3649.324		0000	3655.990		0000
3649.438	Fe	4	3656.080		0000 N
3649.476	Co	3	3656.217		0000
3649.654	Fe, La	5	3656.358	Fe	3
3649.838		00	3656.404	Cr	2
3649.977	Co	1	3656.496		1
3650.178	Fe	4	3656.687		000
3650.423	Fe	5	3656.844		0000Nd?
3650.507		0000	3656.997		0000 N
3650.681		2	3657.104	Co	0
3650.860		0000 N	3657.275	Fe	2
3651.027		0000 N	3657.437		0000 N
3651.179		00	3657.562	Fe	1
3651.247	Fe,-	6	3657.710		0000 N
3651.337		00	3657.850	Fe	1 N
3651.400		0000	3657.957		0000
3651.493		0000 N	3658.044	Co, Fe, Mn	3
3651.614	Fe	7	3658.163		1
3651.794		1	3658.238	Ti	1
3651.940	,-Sc	4	3658.306		0000
3652.061		1	3658.413		0000 N
3652.247		0000	3658.529		000 N
3652.400		00	3658.689 s	Mn-Fe	1
3652.537		0000	3658.783		0000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3659.003		0000 N	3664.760	V	2
3659.109		0000 N	3664.838	Fe	2
3659.263		0000 N	3664.965		000 N
3659.373		0000 N	3665.082		000 N
3659.449		0000	3665.165		00 N
3659.663	Fe	5	3665.325		0000
3659.759		0000	3665.441		0000
3659.901	Fe-Ti	5	3665.574		0000
3660.016		0000	3665.731		0000
3660.109		0000 N	3665.861		00
3660.349		00	3665.987		0000
3660.467	Fe	2	3666.134	Ni	0
3660.549	Mn	1	3666.201	Fe	1
3660.663		0000	3666.301		0000
3660.774	Ti	2	3666.387	Fe	{ 3
3660.916		2	3666.421		{ 2
3661.059		0000 N	3666.504		0000
3661.176		000 N	3666.676		1
3661.289		0000	3666.781	Cr	00
3691.396		0000	3666.907	Fe	3
3661.506	Fe	3	3666.986		000
3661.675		0000	3667.068	Fe	3 Nd?
3661.775		0000	3667.234		0000Nd?
3661.875		0000	3667.397 s	Fe	4
3661.975		0000	3667.561		0000 N
3662.096	Ni	3	3667.741		0000 N
3662.195		0000	3667.887		000
3662.308	Co	1	3668.014		0000
3662.378	Ti	5	3668.133	Fe	4
3662.502		0000	3668.354	Fe, Ni	3
3662.608		0000	3668.491		0000 N
3662.762		0000 N	3668.597	Zr	00
3662.875		000	3668.634		00
3662.978	Fe, Cr	4	3668.796		00
3663.035		0000	3668.907		0000 N
3663.155		0000 N	3669.028	Fe	0
3663.208		0000 N	3669.106	Ti	1
3663.346	Cr	1	3669.292	Fe	2
3663.402	Fe	3	3669.381	Ni	4
3663.541	{ 3		3669.543		00 N
3663.596	Fe	{ 3	3669.666	Fe	4
3663.735		0000 N	3669.823		1
3663.835		0000 N	3669.976	Mn	0000 N
3663.968		0000 Nd?	3670.168	Co	3
3664.104	Fe	2	3670.240	Fe	2
3664.234	Ni	5 d?	3670.356		0000
3664.348		000	3670.446		0000
3664.375		0000	3670.566	Ni	5
3664.548		0000 N	3670.678	Mn	0 N
3664.677	Fe	3	3670.786		0000 N

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3670.860		00 N	3677.231		0000
3670.953	Fe	4	3677.308		0000
3671.046		0000 N	3677.457	Fe	4
3671.226		0000 N	3677.598	Fe	3
3671.358		000	3677.650		3
3671.412	Zr	0	3677.764	Fe	5
3671.506		0000	3677.831		3
3671.660	Fe, Pb	0	3677.991		3
3671.819	Ti	3	3678.045		2
3671.993		0000	3678.236		000 N
3672.083		0000	3678.370		1 Nd?
3672.260		000	3678.491		0000
3672.452		0000	3678.591		0000
3672.601		000	3678.718		0000
3672.742		0000	3678.864		0000
3672.851	Fe	3	3679.002	Fe	4
3672.939		0000	3679.139	Fe	2
3673.049		0000	3679.248		000 N
3673.182		0000	3679.488	Fe	1
3673.226	Fe	3	3679.575		0000
3673.362		0 N	3679.675	Fe	1
3673.562		000	3679.821		2
3673.679		0000	3679.947		0 N
3673.819		00	3680.069 s	Fe	9
3673.909		0000	3680.137		0 N
3674.025	Fe	2	3680.261		0 N
3674.198	Fe	4	3680.347		0000 N
3674.287	Ni	4	3680.525		2
3674.452		0000	3680.641		0000
3674.550	Fe	2	3680.801		3
3674.699		0000	3680.937	Fe	4
3674.865	Zr	1	3681.081		3
3674.909	Fe	2	3681.254		0000
3675.059		0000	3681.368	Fe	2
3675.135		0000	3681.501		0000
3675.255		0000 N	3681.604		0000
3675.430		1	3681.787	Fe	3
3675.585		00	3682.021	Fe	0
3675.692		0000	3682.161	Mn	000
3675.825	V	1	3682.310		2
3675.902		0	3682.382	Fe	5
3676.018		0000	3682.661		00 N
3676.112		000	3682.807		0 N
3676.291		0000	3683.021		000 N
3676.457	Fe, Cr	6	3683.182	Co	3
3676.698	Co	2	3683.229	Fe-V	4
3676.836		0000	3683.514		0000
3676.950		0000	3683.617	Pb?	0000
3677.016	Fe	3	3683.761		2
3677.098		0000	3683.893		0000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3684.020		0000	3690.019	Fe	1
3684.106		0000	3690.053	Ti	2
3684.258 s	Fe	7 d?	3690.205		0000
3684.360		0000	3690.420	V-Pd	1
3684.460		0000 N	3690.599	Fe	2
3684.600	Co-	000 N	3690.732		0000
3684.680	Mn	000 N	3690.870	Co-Fe	4
3684.858		0000 N	3690.999		0000
3685.000		0000 N	3691.112		0000 N
3685.140		000 N	3691.315		000 N
3685.339	Ti	10 d?	3691.452	Fe, Mn	2
3685.665	Mn, Cr	1	3691.534		0000
3685.810		0000	3691.674		0000
3685.913		0000	3691.824		0000
3686.026		0000	3691.954		0000
3686.141	Ti-Fe	6	3692.101		0000
3686.246		0000	3692.251		0000
3686.326		0000	3692.364	V	1
3686.399	Fe, V	3	3692.498		0000
3686.520		0000	3692.578		0000
3686.611		0000	3692.708		0000
3686.813		000	3692.790	Fe	2
3686.926	Cr	1	3692.954	Mn	000 N
3687.010		000	3693.024		0000
3687.083		0000	3693.170	Fe	3
3687.234	Fe	3	3693.258	Co	1
3687.380	Cr	1	3693.384		0000
3687.473		1	3693.504		000
3687.610 s	Fe	6	3693.616	Co	1
3687.690	Cr?	000	3693.804	Mn	0
3687.800	Fe	4	3693.921		0
3687.899		0000	3694.077	Ni	2
3688.005		0000	3694.164	Fe	4
3688.125		0000	3694.344		3
3688.210	V	1	3694.576	La	1
3688.312		2	3694.791		0000
3688.425		0000	3694.954		000
3688.558	Ni	4	3695.041		0000
3688.617	Fe	3	3695.194 s	Fe	5
3688.819		0000	3695.344		0000 N
3688.943		2	3695.479	V	0
3689.013	Fe	1	3695.658	Fe, Mn	1
3689.141		1	3695.789		2
3689.219	Fe	1	3696.006	Fe, V	1
3689.345		0000 N	3696.175	Fe	0
3689.459		000	3696.290		0000 N
3689.513		3	3696.433		0
3689.614	Fe	6	3696.520		0
3689.769		0000	3696.660		000
3689.839		0000	3696.707	Mn	0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3696.800	Mn	0	3703.242		000
3696.890		000	3703.369		000 N
3696.949	Ti	00	3703.586		000
3697.047	Fe, Ni	1	3703.683	Fe-V	{4
3697.243		000 N	3703.729		{3
3697.397		000 N	3703.834	Fe	3
3697.567	Fe	5	3703.962	Fe	2
3697.677		3	3704.176		{2
3697.883		000	3704.221	Co	{3
3698.007		000	3704.341		000
3698.153		1 N	3704 435		00
3698.303	Ti, Zr	2	3704.485	Ti	0
3698.463		000 N	3704.603	Fe	4
3698.613		00 N	3704.842	V	1
3698.744	Fe	4	3704.935		000
3698.830		00	3705.051		000
3698.940		000	3705.171	V	0
3699.023		000	3705.251		000
3699.153	Co	00	3705.401		00 N
3699.283	Fe	3	3705.561		00 N
3699.413		000 N	3705.708 s	Fe	9
3699.533		000	3705.849		2
3699.710		000	3705.968		000 N
3699.877		000	3706.075		00
3699.962		1	3706.175	Mn-	6 d?
3700.062		000	3706.363	Ti	3
3700.182	Ti	00	3706.475		000
3700.269		00	3706.621		000
3700.406		000	3706.701		000 N
3700.479		1	3706.835		000 N
3700.596		000	3707.021		000
3700.737		1	3707.186 s	Fe	5
3700.876		000	3707.315		000
3700.942		000	3707.468		2 N
3701.052		000	3707.600	Co	2
3701.132		000	3707.702	Ti	2
3701.234	Fe	8	3707.815		000
3701.409		000	3707.959	Fe?	5 d?
3701.512		000	3708.068	Fe	5
3701.672		000	3708.224		00
3701.749		000	3708.327		000
3701.866	Mn	0	3708.454		000 N
3702.006		000 Nd?	3708.574		000 N
3702.170	Fe	4	3708.741		1
3702.382	Co	2	3708.834	Ti, V	000
3702.409	Ti	2	3708.964	Co	1
3702.629	Fe	4	3709.170		1
3702.782		000 Nd?	3709.290		00 N
3702.962		000 Nd?	3709.389 s	Fe	8
3703.099		000 N	3709.540		0 N

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3709.675	Fe	1	3716.293		0000 N
3709.808	Fe	1	3716.517		00
3709.967		000	3716.591 s	Fe	7
3710.094	Ti	0	3716.677		00
3710.214		00	3716.838		0000
3710.304		000	3716.905		0000
3710.431 s	Y	3	3717.084		000 N
3710.587		00 N	3717.211		000
3710.777		00 N	3717.326		00
3710.880		000	3717.410		0000
3711.020		000 N	3717.539	Ti	2
3711.254		000	3717.695		0000 N
3711.364	Fe	4	3717.812		0000
3711.440		000	3717.872		0000
3711.552	Fe	3	3717.975		0
3711.674		000	3718.093		000 N
3711.804		000 N	3718.291		0 N
3711.923		000 N	3718.367		000
3712.079		0	3718.460		000
3712.229		00	3718.554	Fe	4
3712.319	Co	00	3718.665		0000
3712.443		000	3718.754		000 N
3712.539		000	3718.845		0000
3712.666		000	3718.978		0000
3712.856		000	3719.070	Mn, Pd	1
3712.906		000	3719.168		0000
3713.037		2	3719.332		0000 N
3713.087	Cr	3	3719.405		0000
3713.239		000	3719.545		0000 N
3713.346		000	3719.598		000 N
3713.479	Ni	00	3719.683		000 N
3713.693		000 N	3719.796[1]		0 N
3713.853	Ti	0	3719.905		0000 N
3713.973		000	3720.084 s	Fe	40
3714.109		000 N	3720.184		0000
3714.296		000 N	3720.305		0 N
3714.359		000 N	3720.400		000 N
3714.546		000	3720.544		00 Nd?
3714.706		000	3720.704		0000Nd?
3714.813		000	3720.832		0000 N
3714.926	Zr	0	3720.930		0000
3715.069		000	3721.048		0000
3715.179		000	3721.171		0000
3715.319		2	3721.212		0000
3715.536		0000	3721.326		2
3715.615	Mn?	4	3721.418	Fe	3
3715.853		0000 N	3721.540	Fe	2
3715.938		0000	3721.647	Fe	2
3716.054	Fe	3	3721.779	Ti	4 d?
3716.172		0000			

[1] This line is variable, though not an atmospheric line.

ON THE OCCURRENCE OF VANADIUM IN SCANDINAVIAN RUTILE.[1]

By B. HASSELBERG.

THE problem of assigning to each chemical element its definitive emission spectrum has been carried perceptibly nearer to its solution, since the necessary basis was established by the classical work of Rowland. Yet when the attempt is made to extend it to the fainter radiations, as well as to the principal lines of the spectrum, the question becomes complicated to such an extent that an exhaustive solution seems to be well nigh hopeless. It is therefore necessary, in this department of spectroscopic research, to be contented with a series of approximations; and no very great surprise need be felt if in a single case, where every effort has been made to eliminate such impurities as were most likely to occur, other impurities have been encountered, the presence of which there was in the beginning scarcely any reason to suspect. The present lines are devoted to a preliminary account of such a case as the above.

For producing the spectrum of titanium in the electric arc I have used titanic acid in the form of rutile with materially better success than when commercial titanium was employed, since the metal burns much too quickly when introduced into the arc, and is scattered in all directions. This rutile, which was kindly obtained for me by Baron Nordenskiöld, comes from Krageröe in Norway. As in other kinds of rutile, its chief component is titanic acid, since, according to analysis of a number of varieties of this mineral,[2] the only other constituent to be expected is oxide of iron in the proportion of from 1 to 2 per cent. After eliminating the iron lines which are thus caused to appear on the spectrograms, as well as other metallic lines, whose presence was revealed by comparison with my own investigations

[1] "Ueber das Vorkommen des Vanads in den skandinavischen Rutilarten." *Bihang till Svenska vetensk. Akad. Handl.* **22**, Afd. 1, No. 7.

[2] Dana's *Descriptive Mineralogy*, 5th edition, 160, New York, 1883.

of metallic spectra and with those of Kayser and Runge, I considered myself justified in ascribing the remaining lines to pure titanium, or at least in considering that only a few isolated cases remained in which contamination by a foreign metal might subsequently be proved. The continuation of my spectroscopic researches has shown, however, that this does not entirely hold good, since among the fainter and faintest lines of my titanium spectrum there are several that doubtless belong to *vanadium*. Having obtained through Baron Nordenskiöld a large piece of this metal, which was made by Moissan of Paris in the electric furnace, I recently began a re-examination of the spectrum, and discovered several strong groups of lines in the blue and violet parts, the approximate wave-lengths of which agreed very closely with those of faint lines previously measured in the spectrum of titanium. In order to obtain a final decision on this point, the parts of the spectrum in question of vanadium and rutile were photographed in juxtaposition on the same plate, in the usual manner, and compared line by line. The result of this investigation of approximate coincidences is shown in the accompanying table.

In the first two columns of this table are given the approximate wave-lengths and intensities of vanadium lines, in the region λ 403–λ 405, for which corresponding fine lines occur on the comparison plates of the spectrum of Norwegian rutile. These lines are given, with their intensities, in the two following columns, the wave-lengths being those of my former catalogue of titanium lines. As will be seen, the coincidences are almost all exact; and hence the corresponding faint titanium lines are to be removed from the titanium spectrum as properly belonging to vanadium.

I must confess that I have been greatly surprised by this result. It will be granted, I think, that there were no possible reasons for suspecting it in advance, since vanadium has never been found in any of the numerous varieties of rutile hitherto known. Under these circumstances it seemed to me desirable to subject another kind of rutile to the same test. For this pur-

Vanadium λ	i	Rutile I λ	i	Rutile II λ	i	Remarks
4033.03	1.2	——				Also a weak line in Ti.
90.70	3	90.73	1			
92.87	3	92.83	1.2			
95.60	3	95.65	1			
4100.00	3.4	4099.94	1.2			Coincident, belong to Va. All the rutile lines are weaker on the comparison plate than here represented.
05.30	3	05.31	1.2			
09.95	3.4	09.92	1.2			
12.00	4	11.91	2.3			
15 30	3.4	15.32	2			
16.65	3	16.64	1.2			
23.65	3	23.68	2.3			Divided. λ Ti > λ Va.
28.25	3.4	28.20	2			Coinc. Belongs to Va.
31.35	1	31.38	1.2			Divided. λ Ti < λ Va.
34.60	3.4	34.60	1.2			Coinc. Belongs to Va.
59.87	2.3	59.79	2.3			Divided. λ Ti < λ Va.
69.45	1.2	69.46	2			Clearly divided. λ Ti > λ Va.
83.45		83.45	1.2			Probably divided. λ Ti > λ Va.
4227.95	2	27.80	2			Widely separated.
68.85	3	——	1	——	1	All these lines occur on the rutile photographs with the observed intensities. The blanks in the columns 3 and 5 of wave-lengths indicate that these lines do not occur in my catalogue of the titanium lines. On the plates here investigated they occur with the given intensities.
71.80	3	——	1	——	1	
4330.15	3	——	1−	——	1+	
33.00	3	——	1−	——	1+	
41.15	3	——	1+	——	1 2	
53.05	3.4	53.01	1	53.01	1.2	
79.45	4.5	79.40	2	79.40	3	
84.90	4.5	84.85	2	84.85	2.3	
90.15	4.5	90.11	2	90.15	2+	
95.40	4	——	2	——	2	
4400.75	4	00.74	1.2	00.74	2	
06.85	4.5	——	1.2	——	2	
07.90	4.5	07.85	1.2	07.85	2+	
08.40	4	08.39	1.2	08.39	2+	
08.65	4.5	08.70	1.2	08.70	2+	
16.65	3	16.70	2	16 70	2	Clearly divided. λ Ti > λ Va.
41.90	3.4	41.86	1.2	41.86		Perhaps. λ Ti > λ Va.
44.40	3.4	44.41	3	44.41		Probably divided. λ Ti > λ Va.

pose Swedish rutile from Käringbricka in Westmanland was chosen, one reason among others for doing so being that the results of Ekeberg,[1] according to which this particular kind also contains chromium, could be tested at the same time. A double exposure to the spectrum of this mineral and of vanadium in the region λ 425–λ 445 having been made, the same series of coincidences was found as in the case of the Norwegian rutile (see the fifth and sixth columns of the table), and hence at the same

[1] *Sevenska vetensk. Akad. Handl.* **46**, 1893. Dana's *Mineralogy*.

time the fact was demonstrated that Swedish rutile also contains vanadium.

If, further, the observed intensities of the vanadium lines which occur in the photographic spectra of the two kinds of rutile are compared, it will be seen that the intensities for rutile II, obtained at Käringbricka, are greater throughout the spectrum than those for rutile I. Since this fact appears to indicate that Swedish rutile contains a greater amount of vanadium than Norwegian, it was of interest to test the relation of the two varieties in this respect by a special experiment, in which the exposure and development were exactly the same. With this object two exposures in the upper region of the spectrum were made on the same plate, using for each a different half of the slit, with electrodes which in one case were made of Norwegian and in the other case of Swedish rutile. The exposure was in each case 1.5 minutes. The developed plate showed the titanium lines with identically the same intensity in both spectra, while the vanadium lines were considerably stronger in the spectrum of the Swedish rutile. In order that this fact may be clearly brought out, I have made the accompanying photographic copy of a drawing,[1] in which the appearance of the negative under the microscope of the measuring engine is represented with all possible exactness. It will be seen that vanadium lines of the Norwegian rutile have a distinctly lower intensity, so that in fact some of the weakest of them fail to appear.

From what has been given above, I believe that it may be regarded as proved that both kinds of rutile contain vanadium, the Norwegian as well as the Swedish, but that the Swedish variety contains a considerably greater amount of this metal than the other. Whether this amount of vanadium is great enough to be recognized or quantitatively determined by ordinary chemical analysis is a question for the solution of which the above experiments afford no data, or at least only such as are highly uncertain, for we have as yet no trustworthy information as to the sensitiveness of the spectral reactions of the elements.

[1] Not reproduced in this JOURNAL.

On the plates which contain the spectra of the two kinds of rutile, the correspondence of lines (leaving out of consideration the difference of intensity of the vanadium lines already mentioned) is complete, with one exception. This exception is found in three quite strong lines which occur in the spectrum of the Swedish rutile, but of which there is scarcely a trace in the other variety. By referring their positions to neighboring titanium lines I obtained for these lines the following wave-lengths:

$\lambda = 4254.50$
74.90
89.90

while the strongest lines in the whole chromium spectrum have, according to my earlier measures, the wave-lengths

$\lambda = 4254.49$
74.91
89.87

The lines therefore belong to chromium, the presence of which is thereby demonstrated, and this result is in agreement with the analysis of Ekeberg.

A NEW FORMULA FOR THE WAVE-LENGTHS OF SPECTRAL LINES.[1]

By J. J. BALMER.

SINCE the wave-lengths of lines in the simple spectrum of hydrogen can be represented with surprising accuracy by a simple formula, it was to be expected that a formula could also be found for the spark spectra of other elements, which would be capable of representing their wave-lengths in a satisfactory manner. Professor E. Hagenbach-Bischoff has been kind enough to send me information from time to time concerning the researches and experiments that have been made in this direction. It is first to be noted, that the spectrum of any metal, as for example lithium or thallium, does not exhibit merely a single series of regularly ordered lines, but several such series, which are in general superposed, and thereby so confused that the lines of the different series appear to be jumbled together without law or order. The circumstance that the lines belonging to any one series have a certain characteristic appearance, so that the lines of one series may be sharp, those of another diffuse on the side toward the red, and those of still another diffuse toward the opposite side, makes it possible to unravel the complex of series; and when this is done it is found that every series approaches with continually narrowing line-intervals a definite and characteristic limit which lies toward the side of shorter wave-lengths. In approaching the limit the lines also become gradually fainter and more indistinct, and thus the difficulties of exact measurements are increased. Professors Kayser and Runge[2] of Hannover, who have investigated the spectra of a great number of elements with extraordinary accuracy and astonishing diligence, and have measured the wave-lengths of the lines in their series, have

[1] "Eine neue Formel für Spectralwellen." *Verhand. d. Naturforsch. Gesell. Basel, Band* 11, *Heft* 3.

[2] "Ueber die Spectren der Elemente." Berlin, 1888 *et seq.*

shown that the oscillation-frequencies, which are inversely proportional to these wave-lengths (or instead of them the reciprocals of the wave-lengths), can be represented by an algebraic series with descending powers of n^2, and that the first three terms of such a series suffice to represent the line series with a very close approximation to the numerical values deduced from observation; the longest and shortest waves perhaps excepted. For determining the three constants in this approximate formula only three oscillation-frequencies determined by measurement are required, for which the numbers n expressing the order must also be known. (For the longest possible wave this number always $= 3$.) The formula itself is, when the reciprocal of the wave-length λ_n is represented by τ_n,

$$\tau_n = A - \frac{B}{n^2} - \frac{C}{n^4}.$$

For representing the longest or at most the two longest waves, the above formula of three terms is not sufficiently accurate, and for this purpose it would be necessary to determine a fourth or fifth constant; but the values of such additional constants would be highly uncertain, since with our present means it is not possible to measure the wave-lengths with sufficient accuracy. (The accuracy at present attainable is about $\frac{1}{100000}$ of a wave-length.) The very simple formula of Kayser and Runge is of the highest value for testing and checking the results of measurement on account of the ease with which the constants can be determined, as it requires merely the solution of an equation of the first degree with three unknown quantities, and it has also served in part to determine the components of the different series. But it cannot be regarded as the real expression of the natural law governing the phenomena of the spectrum. Although the formula as used in practice has only three terms, it is nevertheless to be regarded as a finite or closed function whose denominator contains two terms, developed into an infinite series; and only after we should have succeeded in ascertaining what this closed function is, should we possess the basis for a correct explanation of spectral phenomena. It is

further to be noted that the three constants in the abridged formula of Kayser and Runge do not stand in any demonstrable relation to one another, although the second constant, in any one case, differs by only a few per cent. from a constant mean value.

I have lately made many experiments, which were often abandoned and again renewed, having for their object the discovery of such a closed expression, and in this work the friendly interest of Professor Hagenbach was a constant incentive to effort when there seemed to be no hope of success.

A first short opportunity for examining Messrs. Kayser and Runge's results led me to experiment upon the first line-series of two metals, lithium and thallium, in order to ascertain the most certain method of arriving at a solution of the problem. I observed as a consequence of performing the computations connected with this work, that if the differences of a series of wave-lengths are formed, the quotients obtained by dividing each of two adjoining differences by the next succeeding difference, form a series which answers the requirements almost exactly, and which has the extremely simple form $(n+2):(n-1)$. It is only in the case of the greatest wave-lengths that the error becomes fairly considerable. The law of the series of hydrogen lines is quite accurately represented by the formula:

$$Q_n = \frac{(2n-1)\cdot(n-1)\cdot(n+3)}{(2n+1)\cdot(n+1)\cdot(n-3)},$$

in which the lines λ_{n-1}, λ_n, λ_{n+1} are used in forming the differences. Now, on comparing the corresponding quotients for thallium with those for hydrogen, the striking fact appears, that the two corresponding series do not cover one another, but that one of them appears to be intermittently inserted between the figures of the other. This fact leads to the conjecture that in the true closed formula of the spectrum the integral number n is increased by the addition of some fraction, which is, perhaps, constant. Thus I arrived at the conclusion that the mixed number $n+c$ should be introduced into the formula instead of the integer n, in order to obtain the formula for other elements, and in this way arrived at the expression:

OBSERVED AND COMPUTED WAVE-LENGTHS OF HELIUM LINES.

	Series I α and β			Series II			Series III α and β		
	α computed from lines 1, 3, 9. β computed from lines 1, 3, 7.			Computed from lines 1, 4, 7.			α computed from lines 1, 3, 5 β computed from lines 1, 3, 5.		
	α		β				α		β
	a= 3420.96		3420.99	a=3120.797			a=2599.342		2599.317
	b=3.758942		3.756648	b=3.427311			b=2.871562		2.869745
	c=1.999392		1.998615	c=2.011946			c=1.942689		1.941889
n	O.	C.	Diff.	O.	C.	Diff.	O.	C.	Diff.
1	5876.206	5876.206	0.	5015.73	5015.73	0.	3888.97	3888.97	0.
	5875.883	5875.880	−0.03				3888.76	3888.76	0.
2	4471.85	4471.870	+0.02	3965.08	3965.031	−0.049	3187.98	3188.313	+0.333
	4471.66	4471.610	−0.05	3964.84		+0.191	3187.83	3188.115	+0.285
3	4026.52	4026.523	+0.003	3613.89	3613.872	−0.018	2945.57	2945.57	0.
	4026.35	4026.350	0.	3613.78		+0.092	2945.42	2945.42	0.
4	3819.89	3819.891	+0.001	3447.73	3447.73	0.	2829.32	2829.406	+0.086
	3819.75	3818.770	+0.02				2829.16	2829.286	+0.126
5	3705.29	3705.247	−0.043	3354.7	3354.635	−0.065	2764.01	2764.01	0.
	3705.15	3705.16	+0.01				2763.91	2763.91	0.
6	3634.52	3634.451	−0.069	3296.9	3296.817	−0.083	2723.3	2723.302	+0.002
	3634.39	3634.39	0.						
7	3587.54	3587.461	−0.079	3258.3	3258.300	0.	2696.5	2696.153	−0.347
	3587.42	3587.42	0.						
8	3554.5	3554.59	+0.09	3231.3	3231.276	−0.024	2677.1	2677.101	+0.001
		3554.56	+0.06						
9	3530.6	3530.65	+0.05	3213.4	3211.565	−1.835			
		3530.63	+0.03						
10	3512.6	3512.66	+0.06						
		3512.65	+0.05						
11	3498.7	3498.78	+0.08						
		3498.78	+0.08						
12	3487.8	3487.85	+0.05						
		3487.85	+0.05						
13	3479.2	3479.09	+0.11						
		3479.09	+0.11						

$$\lambda_n = a\frac{(n+c)^2}{(n+c)^2-b}\text{; or, } \tau_n = A - \frac{B}{(n+c)^2}.$$

I first tested this formula on the series I of lithium. Previous experiments had shown that for this element the constant a is about 2300 tenth-meters. With the value 4 for b, the value determined for c was 0.72332, and with these constants the computed wave-length of the second line at λ2741.39 was 2802, or about 60 units too great. For $a = 2300$ and $b = 3$ (instead of 4), and with the corresponding value $c = 0.2245$ deduced with their

OBSERVED AND COMPUTED WAVE-LENGTHS OF HELIUM LINES.

	Series IV.			Series V α and β			Series VI.		
	Computed from lines 2, 3, 4. $a=3678.613$ $b=4.042545$ $c=2.000229$			α computed from lines 2, 5, 8. β computed from lines 2, 5, 8. α: $a=3421.275$ $b=3.746843$ $c=1.696996$ β: $a=3421.109$ $b=3.747853$ $c=1.697826$			Computed from lines 1, 4, 7. $a=3679.022$ $b=4.027016$ $c=1.852937$		
n	O.	C.	Diff.	O.	C.	Diff.	O.	C.	Diff.
1	6678.1	6677.5	−0.6	7065.77*	7055.86	−9.91	7281.8	7281.81	+0.01
				7065.51*	7054.83	−10.68			
2	4922.08	4922.08	0.	4713.39	4713.39	0.	5047.82	5048.529	+0.709
				4713.17	4713.17	0.			
3	4388.11	4388.11	0.	4121.15	4121.196	+0.046	4437.73	4437.859	+0.129
				4120.98	4121.047	+0.067			
4	4143.91	4143.91	0.	3867.77	3867.790	+0.02	4169.12	4169.12	
				3867.61	3867.652	+0.042			
5				3733.15	3733.15	0.	4024.14	4024.083	−0.057
				3733.01	3733.01	0.			
6				3652.29	3652.261	−0.029	3936.1	3936.051	−0.049
				3652.15	3652.118	−0.032			
7				3599.59	3599.588	−0.002	3878.3	3878.3	0.
				3599.45	3599.443	−0.007			
8				3563.26	3563.26	0.	3838.2	3838.237	+0.037
				3563.11	3563.11	0.			
9				3536.9	3536.946	+0.046	3808.3	3809.256	+0.956
10				3517.5	3517.452	−0.048			
11				3502.5	3502.530	+0.03			
12				3490.8	3490.839	+0.039			
13				3481.5	3481.514	+0.014			

*Phot. (sic). This line was measured optically. *Ap. J.*, **3**, 7. Eds.

aid, the computed wave-length of the second line was 2764.76 or still too great by 23.37 units. A third trial with $b=2.5$ made $c=-0.05646$ and the second wave-length 2740.56, thus only 0.83 units too small. The computation when extended to the following lines, with the constants last determined, gave results which in the average deviated by only about one-fourth of a unit from the measured wave-lengths. Since only round numbers were used for the first and second constants in this first trial of the new formula, I was greatly surprised at the close agreement of the result, and the

conviction fastened itself upon me that this formula was an adequate expression of a physical truth.

Professor Albert Riggenbach remarked to me, on the occasion of an incidental meeting, that Professors Runge and Paschen had published extremely accurate measures of the lines of helium,—an element which was first discovered in the chromosphere and in some of the Orion stars, but which had not been found in terrestrial substances until very lately, when it was found to exist as clèveite gas in certain minerals,—and he suggested that these measurements would in all probability be very suitable for testing the closed formula. The next day he sent me the figures for the three double series and the three single series of helium lines, according to the communication of Runge and Paschen,[1] and an account of the lines in clèveite gas ascribed by Lockyer to helium, together with the complete general solution of the equation of the third degree with three unknown quantities which is implied in the formula. I here desire to extend my best thanks to Professor Riggenbach for his kind assistance, hints, and communication of facts. The figures which he sent me have been used in my computations, and the results which I have found are exhibited in the tables given above. In the double series, I, III and V, Runge and Paschen have not represented the shortest pairs as divided, no doubt because these pairs are too close and too faint for exact observation. The numbers given for them have therefore one decimal place less than the double lines of the series.

In computing the constants the choice of the lines on which the computation is based has a very great influence on the result, particularly in the case of the longest waves. If, on account of small errors of observation, the adopted values of the wave-lengths differ even very slightly from the true values, the computation of the constants is considerably affected, and this influence is most felt in the greatest wave-lengths with smallest values of n,—not so much through the influence of the con-

[1] *Mathem. u. Naturw. Mittheilungen d. K. preuss. Akad. Wiss.*, Berlin, 323, 377. 1895.

stants a and b as through that of c. When therefore the computed values obtained with the formula are found to deviate here and there from the results of observation, in the case of the longest waves of a series, this fact may be ascribed to the great difficulty of determining the constants, rather than to deficiencies of the formula. It is presumable that in series where observation and computation are at variance in the greatest wave-lengths, complete agreement could be brought about by a suitable change in the constants.

Testimony in favor of the closed new formula is found in its simplicity, which is only equaled by that of the accepted hydrogen formula, and further in its intimate relation with the latter, which is only a special form obtained from the new formula by placing $b=4$ and $c=0$. Still another advantage of the new formula seems to lie in this, that it is now a matter of indifference what integral value is given to n, so long as the lines of a series, and therefore the values of n, progress uninterruptedly ; for by as much as n is taken greater or smaller, compensation to that amount is effected by the smaller or greater value of c.

With regard to the meaning of the constants, that of a is quite plain ; it indicates the limiting wave-length in which the series of lines terminates. The constant c, on the other hand, indicates the displacement by which the integral values of n must be increased or diminished ; a fraction which is constant for one and the same series. The least intelligible significance is that which attaches to the constant b, by which the square of $n+c$ in the denominator is diminished. This constant seems to have the character of a square quantity ; for if the constant b in the typical hydrogen formula is diminished from 4 to 1, only the wave-lengths of the originally even values of n remain, and the uneven wave-lengths disappear, so that the curve of wave-lengths is reduced one-half, a change which is repeated in a corresponding manner when other quadratic values are given to b.

The constant b has a quite remarkable relation to the con-

stant a. If for any series of lines a is divided by b, a number is obtained which is equal to within about ½ per cent. to the corresponding quotient for the simple series of hydrogen. The latter quotient is $3645.6 : 4 = 911.4$. The corresponding quotient for the helium series I α and β, II and IV, is a little more than 910, and therefore about 0.1 per cent. less than for hydrogen; for series III α and β it is over 905; for series V α and β, and series VI it is nearly 913. For the lithium (single) series I a computation based on the lines 1, 4 and 7, gives for the values of the constants, $a = 2299.401$, $b = 2.514417$; if lines, 1, 3 and 5, are taken the values are $a = 2298.643$, $b = 2.536159$. The quotient of the first pair of constants is 914.48, that of the second only 906.20. The mean of the two is 910.34. As I have already remarked it is possible that such discrepancies in the values arise from the unavoidable minute errors of observation, so that a definite judgment as to the incorrectness of the formula should not be based on them. These remarkable approximations to a constant mean value do not at any rate exclude the possibility that we are here dealing with relations that are founded on fact, and that offer to us, like so many others that occur in nature, enigmas to attempt the solution of which there is always an irresistible charm.

ADDENDUM.

Through the kindness of Professor Hagenbach, who lent me the memoir of Messrs. Kayser and Runge for the purpose of more detailed study, I have had the opportunity of becoming acquainted not only with their own results, but with their highly interesting account of a formula proposed several years ago by the Swedish savant Rydberg.[1] The closed formula above given agrees almost perfectly with Rydberg's formula, the only difference being that the constant B $(= \frac{b}{a}$ of the former), instead of having a particular value for each element, is assumed by Rydberg to have a value which is the same for all the elements,

[1] "Spectren der Elemente," 4 Heft, Nachtrag, 61.

(109721.6, or the reciprocal of 911.4 of hydrogen), and therefore equal to the corresponding constant of the hydrogen formula. It may be conjectured that Rydberg has chosen this value for the basis of his formula, because it represents the mean of the corresponding constants for all the other elements, and because this assumption greatly simplifies the computation of the two remaining constants;—for a direct determination of all three constants from three measured wave-lengths requires the some what tedious solution of an equation of the third degree.

Messrs. Kayser and Runge have shown that the original formula of Rydberg leads to less satisfactory results than their abridged series; nevertheless Rydberg ascribes to his own formula greater pretensions to correctness.

Kayser and Runge have further shown that even a modification of Rydberg's formula obtained by giving special values to B in his equation

$$\tau_n = A - B\,(n+c)^{-2}$$

furnishes no better results than three terms of their series of powers. But since Kayser and Runge have not described the manner in which they determined the value of the constant B, it may be assumed as probable that they have used the values of B deduced from their own formula as a basis for this modification. By this process, however, the correctness of the modified Rydberg formula, in the form which I have independently discovered, is not yet disproved; for the direct determination of the three constants in the formula

$$\tau_n = A - B\,(n+c)^{-2}, \text{ or } \lambda_n = a + \frac{b}{(n+c)^2 - b},$$

in which $A = \frac{1}{a}$ and $\frac{B}{A} = b$, does not lead to the same values of B as the formula

$$\tau_n = A - Bn^{-2} - Cn^{-4}.$$

Since the deviations of the second constant B from a mean value are comparatively small for all the elements in both formulæ, Messrs. Kayser and Runge are led to remark that "Rydberg's assumption is possibly so far correct, that in the still

hidden true law this constant represents one and the same value throughout."[1]

Rydberg found that for all elements the curve determined by erecting ordinates proportional to the wave-lengths, at equal intervals corresponding to successive values of n as abscissæ, resembles a hyperbola, since it approaches lines parallel to the axes as asymptotes.

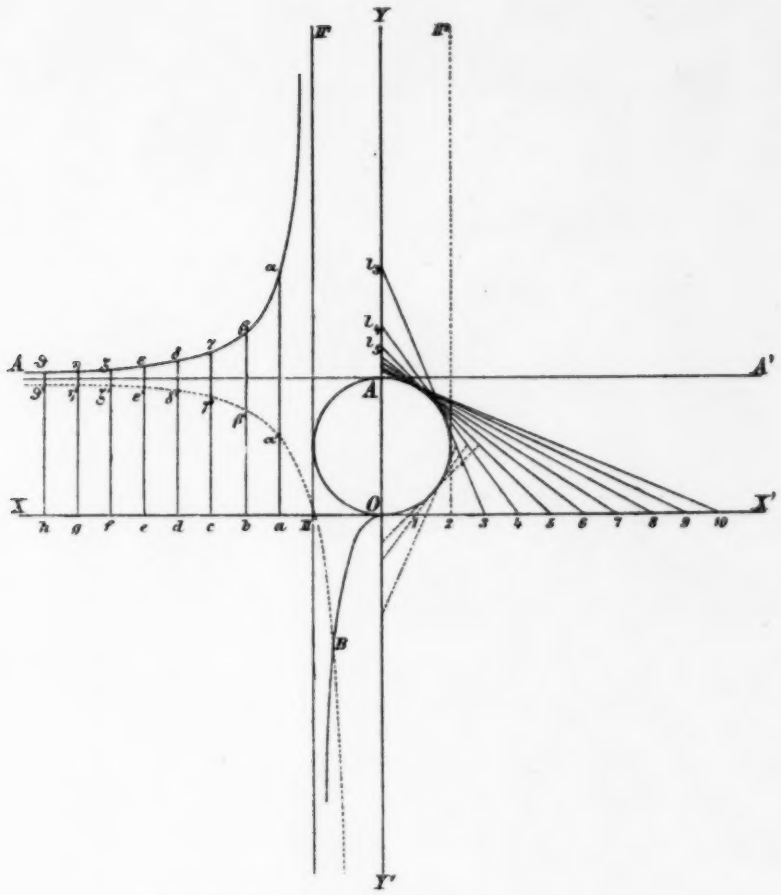
If we test the character of the curve for the simple hydrogen spectrum, where the relations are simplest and clearest, and take into account all (including negative) values of n, we shall find that the curve is of the third degree, with three asymptotes (see the figure). The single horizontal asymptote lies at the distance a above the axis of abscissæ. On each side of the axis of ordinates, parallel to the latter, and at a distance from it equal to $2n$, is a vertical asymptote. The curve itself has three branches: two of a generally hyperbolic form above the horizontal asymptote, separated from each other by the interval $4n$ between the vertical asymptotes, and a third between the vertical asymptotes, having its vertex at the origin, with infinite branches which form a transition to the hyperbolic curves above.

The curve of reciprocals of wave-lengths in the hydrogen spectrum (taking as unit $a = 4n$) is easily shown in its relations to the wave-length curve. It also is a curve of the third degree, and consists of only two branches, which as before resemble the hyperbola in form. They have the same horizontal asymptote as the wave-length curve, and a single vertical asymptote, which is the axis of ordinates. These branches pass through the intersections of the vertical asymptotes of the wave-length curve with the axis of abscissæ, and approach the axis of ordinates as asymptote below, having a cusp at infinity.

In the accompanying figure (Plate VIII) XX' is the axis of abscissæ, YY' the axis of ordinates, O the origin; AA' is the horizontal asymptote and II, II' and $2II^2$ are the vertical asymptotes; $\alpha\beta\gamma$, etc., is the wave-length curve of hydrogen; $a\alpha$ the wave-length γ_3, $b\beta = \lambda_4$, etc. The curve of reciprocals is $B\,II\,\alpha'\,\beta'\,\lambda'$,

[1] *Spectren der Elemente*, IV Abschnitt, 63.

PLATE VIII.



α β γ δ ϵ ζ η θ : Curve of Wave lengths.
α′ β′ γ′ δ′ ϵ′ ζ′ η′ θ′ : Curve of Reciprocals.

etc., $a\alpha'$ being the reciprocal of λ_3, $b\beta'$ the reciprocal of λ_4 or $b\beta$, etc. Only half of each curve is drawn; the other half may be readily supplied, the curves being symmetrical with respect to the axis of ordinates.

A very simple construction of the hydrogen wave-lengths is shown on the right side of the figure. Let OA on the axis of ordinates represent the constant a, or the lower limit of the hydrogen wave-lengths, and let a circle be described having $AO = 3645.6$ Ångström units as a diameter; then if tangents are drawn to the circle from the points $n = 1, 2, 3$, etc., on the axis of abscissæ (the unit is taken to be $1n = \frac{1}{4}a = 911.4$), their intercepts on the axis of ordinates will represent the wave-lengths.

The correctness of the construction may readily be proved.

This construction may possibly be useful in throwing a new light on the mysterious phenomena of the spectral lines, and in leading to the right way of finding the real closed formula for spectral wave-lengths, in case it has not already been found in the formula of Rydberg.

The final impression, which our mind involuntarily receives in contemplating these fundamental relations is that of a wonderful mechanism of nature, the functions of which are performed with never-failing certainty, though the mind can follow them only with difficulty and with a humiliating sense of the incompleteness of its perception.

Ritz.

Minor Contributions and Notes.

NOTE ON A CAUSE FOR THE SHIFT OF SPECTRAL LINES.

I would call attention to a cause for the shift of the lines that Messrs. Jewell, Humphreys, and Mohler have been investigating with so much skill and success, which is allied to Professor Schuster's suggestion[1] but is so far distinct that it is not disproved by the observation that the shift is independent or largely independent of the amount of the substance in the arc.

When a body is a source of electromagnetic radiations the frequency of its vibrations depends in general on the specific inductive capacity of the medium in which it is immersed. An electromagnetic oscillator performs oscillations that can be calculated from a formula of the form $N^{-2} \alpha L C$, where L is self induction and C is capacity. If the medium have a high electric inductive capacity C will be large and consequently N will be small. Now an increase in the pressure of a gas increases its specific inductive capacity and must in consequence alter to some extent the period of vibration of the molecules in it, if their period of vibration depends at all on electric forces due to constant charges. We can consequently conclude that here is certainly a *vera causa* for some shift towards the red in molecules causing light, for in them there can be no doubt that electric forces are at least a part of the forces affecting the periods of vibration.

We can see that the complete solution of the question from this point of view is very complex. On the molecular scale we cannot deal with a gas as a continuous medium having a definite calculable specific inductive capacity. It is a very complex question how far an average specific inductive capacity in its neighborhood would control the vibrations of an electric oscillator. It would depend on the extent to which the oscillator was or was not self contained. Now what is called the dimension of a molecule is a measure of the extent of its action on its neighbors and consequently of their reaction on it. There is consequently reason to expect that some such rela-

[1] This Journal, 3, 292, 1896.

tion as has been observed should exist between the dimension of the molecule and the amount of the shift. In some of the cases I have tried there seems to be some connection between the refractive index of the gas and the amount of the shift, but I would not expect much connection of this kind to exist because the principal cause for a change in the specific inductive capacity would be the high pressure air present, which is the same in all the cases observed, and secondly because the refractive index is a measure of the average specific inductive capacity only, and from this alone we could not expect to calculate the amount of the shift in each case because, as I said, this latter will depend partly on how far this average specific inductive capacity is able to alter the vibration periods of the molecule. It is evident, for instance, from the experiments that the influence of the cause, whatever it is, on some of the calcium movements that underlie certain of the lines is much greater than its influence on other movements underlying other lines.

Everybody must feel the very greatest interest in this work. It is bringing us measurably nearer a knowledge of atomic movements and interactions, the great goal of modern physical research.

TRINITY COLLEGE,
Dublin.

GEORGE F. FITZGERALD.

NOTE ON A FORM OF SPECTROHELIOGRAPH SUGGESTED BY MR. H. F. NEWALL.

IN a recent number of the *Proceedings of the Cambridge Philosophical Society*[1] Mr. Newall publishes an interesting suggestion for a new form of spectroheliograph.

After describing several instruments previously employed by M. Deslandres and the writer he suggests that some modification of Littrow's spectroscope with fixed slits would seem to offer obvious advantages for these investigations. The proposed spectroheliograph consists of a single telescope, which serves as both collimator and camera, with a grating (or train of prisms) attached by means of a suitable framework at the objective end. The slits are fixed on opposite sides of the eye-end of the telescope. Light entering the first slit meets a right-angle prism near the axis of the telescope, from which it is reflected into the collimator lens. The spectrum formed by the

[1] *Loc. cit.*, **9**, 179, 1896.

grating is returned through the tube, falls upon a second right-angle prism, and is brought to focus on the second slit. By simply rotating the grating any desired line may be made to pass through this slit. The solar image and the photographic plate are in parallel planes, and remain fixed in position while the spectroheliograph is moved in the direction of its optical axis. Mr. Newall suggests that such an instrument be mounted like the bob of some forms of ballistic pendulums, with the slits vertical when at rest, the first slit bisecting the solar image formed by a coelostat. It is then to be set swinging with an amplitude slightly greater than the diameter of the Sun's image, and allowed to swing long enough to give a sufficient exposure.

As Mr. Newall remarks, a spectroheliograph embodying the Littrow principle was built for the writer some years ago. Mr. Newall's proposed instrument is decidedly superior to that particular piece of apparatus, which was designed to be used under circumstances such that movement as a whole was inadmissible. Since that time exactly such an instrument as that now described was suggested by Professor Wadsworth, in the course of our discussion relative to the design of the large spectroheliograph for the 40-inch refractor of the Yerkes Observatory. The plan of suspending the instrument like a pendulum, which was considered by the writer when the spectroheliograph belonging to the late Mr. Ranyard was being designed, was abandoned for the reason that the first slit would not remain parallel to itself during the exposure if the instrument were mounted in this way. Thus the lines in the photographed solar image which are due to dust on the slits would be curved instead of straight, and it would be troublesome, in measuring the photographs, to apply corrections necessitated by the curvature of the spectral lines. The distortion due to this curvature, while very considerable with prisms, is also by no means inappreciable with gratings. To remove this difficulty Professor Wadsworth has suggested that the spectroheliograph be suspended on some system of link-work giving a parallel motion. In this form it could be used to good advantage with a coelostat, though I am not sure that equally good results could not be secured with an instrument carried by ball bearing wheels rolling on rails.

After using many different forms of spectroheliograph, the writer is of the opinion that the type represented by the Ranyard instrument is probably as good as any other, at least for use in an invariable plane. For some reasons it would be of advantage to insert two right-angle

prisms, as Mr. Newall suggests, in order to make the motion parallel to the axis of the collimator, and to give more room for the photographic plate holder, or the camera box used with an enlarging lens. But it would probably be better to avoid the Littrow form, in spite of its simplicity, rigidity and compactness, unless the difficulties due to scattered light can be eliminated. It is true, as Mr. Newall remarks, that the central reflections can be partially or wholly stopped out, but the fact remains that the objective is illuminated by the sunlight passing through the first slit, and it is difficult to protect the sensitive plate from the scattered light.

The principal objection to the type of spectroheliograph just referred to is the considerable mass of the moving parts. This is not very serious when the instrument is used with a heliostat or coelostat, where it can easily be counterbalanced. But when it must be attached to the eye end of an equatorial the difficulties are much greater. For this reason experiments are now being made at the Yerkes Observatory to test one of the ingenious forms of moving slit suggested by Professor Wadsworth.[1]

It should be added that the spectroheliograph, whether used with an equatorial or a coelostat, should be so mounted that it can be rotated in position angle. Considering the distortion due to curvature of the spectral lines, which is inevitable in all forms of the instrument hitherto constructed,[2] it is a matter of some practical importance to be able to place the slit parallel to the Sun's axis before making an exposure.

Mr. Newall's suggestion that the spectroheliograph be made to move rapidly across the Sun's image several times during a single exposure seems to me a good one. Images free from the very objectionable lines due to inequalities of motion could undoubtedly be obtained in this way. The suggested pendulum support would be very convenient for exposures of this kind, but it may be doubted whether this advantage would offset the disadvantages already mentioned.

It is to be hoped that Mr. Newall will decide to have constructed a spectroheliograph embodying some of the new ideas.

GEORGE E. HALE.

YERKES OBSERVATORY,
February 1897.

[1] This JOURNAL, 1, 244, 1895.

[2] MR. W. H. WRIGHT, of the Yerkes Observatory, has suggested a method of correcting this distortion.

NOTE ON STEADY LIQUID SURFACES.

In some experiments carried out in the spring of 1894 in which it was necessary to obtain a sharp image of a line by internal reflection from a liquid, it was found impossible to use a polished glass surface of sufficient extent placed in contact with the liquid. It became necessary to test the conditions for damping of earth tremors and air disturbances.

Of several piers, one was selected showing the least disturbance on a mercury surface. Such a liquid surface, when the containing vessel was placed upon a thick layer of felt on a pier, showed most marked tremors at any time of night when local street traffic had ceased. A 4-inch collimator and telescope at an angle of 60° or more incidence and with the eyepiece removed, showed in a most interesting way the ripples produced by a switch engine three-quarters of a mile away in the dead of night. With the eyepiece in, the image of the slit appeared fairly sharp. A second float containing mercury, placed on the first surface, showed nearly the same effect. A water surface upon this showed the same. The ripples did not originate at the edge of the surface much of the time.

An attempt was then made to destroy the tremors by greatly increasing the inertia of the support, by piling up for a couple of feet alternate layers of thick felt and iron, weighing several hundred pounds. With the mercury surface resting upon this, and with the eyepiece of the telescope removed, ripples, arising from tremors, could still be seen under the most favorable circumstances.

Heavy masses supported by elastic means of different kinds showed the ripples still. A pneumatic arrangement gave the most promise, as evidently here, if the reservoir is large and the supporting area small, the transmitted changes of pressure can be almost eliminated; but in all cases of springs supporting masses, short period tremors seemed to be communicated through the spring itself and the envelope, in the case of air.

A different arrangement was then tried with success, consisting of four boxes fitting within one another with a clear space of from one to two inches between them. The outer one, about $50 \times 10 \times 10$ inches, was placed upon felt layers on the pier, and the space between it and the next filled with cylinder oil (medium). The second was ballasted with iron and the third placed within it upon layers of cotton. The

space between three and four was likewise filled with oil. Number four was ballasted and a support for a tube was placed within it on cotton layers. The whole arrangement was protected from air disturbances.

A horizontal tube, 50 × 2 inches, with capped ends and partly filled with water, showed no evidence of ripples under favorable circumstances. A telescope of 1-inch apertnre and an angle of incidence of 89°, so that the light was incident over the full length of the surface, showed a resolving power of about 1″ for 1-inch aperture, the calculated limit. Of a number of different liquids, used without jacketing the tube, water was the only one which gave for internal reflection for this length of tube, clear definition. All gave good definition for external reflection. With mercury and water upon mercury the full resolving power of the telescope was obtained.

The results indicate that there is more chance of transmitting rapid vibrations through elastic supports than through very viscous floats. Elastic supports for masses of great inertia may protect from slow disturbances as well as floats, but the latter seem to damp all vibrations most completely.

Position and steadiness can be obtained, if necessary, by a light packing of cotton in the surface of the oil. This was found not to affect the result in definition. Little was gained by making the thickness of the layer of oil large. A viscous liquid was found much superior to any other, such as water or mercury, as the ripples in the latter are not damped rapidly enough, and communicate disturbances. Of course everything must be protected from air currents, particularly the surface to be observed, as these are some of the chief disturbing elements.

D. B. BRACE.

AWARD OF THE GOLD MEDAL OF THE ROYAL ASTRONOMICAL SOCIETY TO PROFESSOR BARNARD.

I TAKE great pleasure in announcing that the Royal Astronomical Society has awarded the gold medal to Professor E. E. Barnard, Astronomer of the Yerkes Observatory, for his contributions to astronomical science. These include his discovery of the fifth satellite of Jupiter, micrometric measures of planets, asteroids, satellites, nebulæ, and comets, numerous discoveries of comets, photographs of the Milky Way, comets, nebulæ, and other objects with a portrait lens, and other

important observations. All of his colleagues at the Yerkes Observatory unite in extending to Professor Barnard their heartiest congratulations upon this well-deserved recognition of his work.

GEORGE E. HALE.

ON THE MODE OF PRINTING MAPS OF SPECTRA.

THE following remarks are quoted from the report in the February *Observatory* of the discussion at the meeting of the Royal Astronomical Society on January 8. They are of interest in connection with Professor Kayser's proposal that the mode of printing maps and tables of wave-lengths, adopted by the Board of Editors of this JOURNAL in 1895, should be reversed.[1] Further expressions of opinion will be gladly received by the editors for publication in the ASTROPHYSICAL JOURNAL.

The order of decreasing wave-lengths has been followed throughout; and I much regret that many astrophysicists have recently decided to follow the reverse order of the pianoforte keyboard in the order of the spectrum lines.
—*Rev. W. Sidgreaves.*

I was extremely pleased to hear Father Sidgreaves' opinion as to the place in which the red end of the spectrum should be drawn, because, like himself, I am a heretic on that point. The ASTROPHYSICAL JOURNAL has laid down the law that the red end should be to the right, but I think the whole analogy is the opposite way. I showed some slides of the spectrum of helium here some time ago, and in those slides the red end was put to the left, and this arrangement was criticised; but it was necessary it should be so, because I was dealing with the question of series of lines, and it seems to me we can only deal with a series of lines by beginning with the left end, in the same way as we begin on the left-hand side of the page of a book. There is also the analogy of the piano. I shall be glad to see a reversal of the decision of the ASTROPHYSICAL JOURNAL.—*Mr. Maunder.*

I think they are reopening the question.—*Mr. Newall.*

The delineation of the spectrum from left to right in accordance with the increase of wave-lengths was adopted by Kirchhoff, Thalén, and Ångström, also by Huggins, Lockyer, Cornu, Dunér, Draper, Pickering, Rowland and others.—*Mr. McClean.*

On the subject of the arrangement of spectrum lines referred to by Mr Maunder, Mr. McClean, and Father Sidgreaves, I think that for the proper

[1] See this JOURNAL, 4, 306, November 1896.

representation of the spectrum scale the small wave-lengths ought, as in the high keys of a pianoforte, to be placed on the right.

—*Prof. Alexander Herschel.*

SALE OF INSTRUMENTS AND DRAWINGS FROM THE COLLECTION OF THE LATE M. TROUVELOT.

We desire to call attention to the fact that the following instruments and drawings, which belonged to the late M. Trouvelot, of the Observatoire de Meudon, are now offered for sale by his family.

(1) A photographic telescope with enlarging apparatus, especially designed for solar photography. The object glass, by Brashear, is of 15^{cm} clear aperture and $200^{cm}.8$ focal length, and is corrected for the region near G. The tube and other metallic parts are by Bardou of Paris. A brass dew-cap 50^{cm} long, provided with hinged cover, forms part of the instrument. The telescope tube is perforated by two openings 180° apart, for the purpose of allowing both sides of the objective to be brought to the same temperature. The tail-piece carries a tube moved by rack and pinion, with scale and vernier for accurate setting. There are two amplifying eyepieces by Brashear. No. 1 gives an image of the Sun 100^{cm} in diameter at a distance of 100^{cm}. No. 2 gives an image 20^{cm} in diameter at a distance of about 50^{cm}. The photographic camera attached to the lower end of the tube is provided with all necessary adjustments, and is designed to carry a plate $25^{cm} \times 25^{cm}$. It contains a special curtain-shutter for giving very short exposures. The adjustable slide in the curtain can be given any opening up to 1^{cm}. Attached to the telescope is a Secretan finder, with an eye-piece which projects the solar image upon a ground-glass supported in a brass cone. The price of this instrument complete is 5000 francs.

(2) A comet seeker of 10^{cm} clear aperture and 145^{cm} focal length. Near the center of the tube a large right-angle prism is mounted so that the observer always looks in a horizontal direction. The mounting is in the alt-azimuth form, and a hand wheel is provided for moving the telescope, which is suitably counterbalanced. A metal strap with pivot is so arranged that the instrument can be mounted upon a suitable column. The metal work of the tube is of polished and lacquered brass. A low power (Clark) eyepiece accompanies the telescope, which is offered for 1500 francs.

(3) The original pastel drawings of various astronomical objects made by the late M. Trouvelot. Many of these are familiar through the reproductions published in the United States, where the drawings were made.

For further information, intending purchasers should address M. Georges H. E. Trouvelot, 23, rue des Capucins, Meudon, Seine et Oise, France.

ERRATA.

THE following corrections should be made in Mr. Jewell's article in the December 1896 number of this JOURNAL:

Page 328, for *amplitude* read *azimuth*.

Page 335, Table IV, for βm read m.

Reviews.

Ueber einen Versuch eine electrodynamische Sonnenstrahlung, und über die Aenderung des Uebergangswiederstand bei Berührung zweier Leiter durch electrische Bestrahlung: J. Wilsing und J. Scheiner. *Wied Ann.* **59**, 782–792, 1896.

At the Astrophysical Observatory in Potsdam, Messrs. Wilsing and Scheiner have been making a careful search for the presence of long electromagnetic waves in the solar radiation. It was, from the outset, expected that, if such waves were emitted by the Sun at all, their intensity would be greatly diminished on passing through the Earth's atmosphere.

The determining factor, therefore, in the selection of a detector was *sensibility*. Accordingly Lodge's form of Branly's Coherer, a "bridge" of three steel wires, was selected. Of these three wires, two are laid parallel and the third is laid across the two; the battery and galvanometer are joined in series with the bridge thus formed. The whole was then placed in a metal case to shield it from outside disturbances. In the top of this case was an opening fitted with a metallic reflector, which could be used to direct any desired radiation upon the "bridge." This simple and extraordinarily sensitive instrument proved itself much like other sensitive instruments, viz., unreliable in its very small indications. A heliostat fitted with a metallic mirror directed the solar radiation toward the receiver. Two paper screens, transparent to long waves, kept out the heat and light.

As to results, nothing positive was attained. The indications due to solar radiation, if any, were less than the errors in reading the galvanometer scale.

This interesting attempt to extend the solar spectrum reminds us of a fact which cannot be over-insisted upon at this time, viz., there is a very wide difference between assuming on mathematical grounds and proving by experiment, the continuity of the properties, or even of the existence, of all waves intermediate between the very short ones photographed by Schumann and the very long ones studied by Hertz.

H. C.

Total Eclipse of the Sun, April 16, 1893. Report and Discussion of the Observations relating to Solar Physics. By J. NORMAN LOCKYER, *Phil. Trans.*, **187**, pp. 551–618, 1896.

THE exceedingly interesting and important results obtained by Mr. Shackleton at the eclipse of last August in photographing the spectrum of the "flash" immediately preceding totality, have directed attention to the important part played by the prismatic camera in eclipse observations. The results secured by Mr. Shackleton will be described and illustrated in a subsequent number of this JOURNAL. At present we must confine our attention to the almost equally valuable results obtained by Messrs. Fowler and Shackleton at the eclipse of April 16, 1893. The reports of Messrs. Fowler and Shackleton, together with a discussion of the results by Professor Lockyer, are contained in a memoir recently published in the *Philosophical Transactions.*

The memoir opens with an introductory statement by Professor Lockyer, in which a brief historical sketch of the use of the prismatic camera in earlier eclipses is given. In 1871 Respighi and Lockyer first used this instrument for eclipse work. Previous to this time it had been employed by Fraunhofer in his early observations of the spectra of the stars, and later by Secchi in his stellar spectroscopic work and by Respighi in certain special observations of the Sun. In 1871 Resphigi used a single prism over the object-glass of his telescope, and Lockyer employed a train of five prisms without either collimator or observing telescope. At the beginning of totality Respighi saw the chromosphere in the lines C, D_3, F and G, and later three bright rings, which he considered to correspond with C in the red, 1474 in the green, and F in the blue. Of these the green ring was the brightest, most uniform, and best defined. Lockyer's observations were made 80 seconds after the beginning of totality. He saw the C ring very bright, 1474 and G faint, and F of intermediate intensity.

In 1875 photography was first employed in eclipse work with the objective prism, but the dispersion was so small that the results were of no great value as compared with those subsequently obtained. In 1878 no bright rings were recorded. In 1882 Dr. Schuster photographed a green ring corresponding to 1474, and a yellow one which he believed to coincide with D_3. In 1883 the same instrument used in the preceding year was employed, but gave no valuable results. The same camera was again employed in 1886, and recorded the spectra of

some prominences, but apparently gave no rings. In 1893 prismatic cameras were used by Messrs. Fowler and Shackleton, and with them photographs were obtained which are far superior to those secured at previous eclipses.

The prismatic camera used by Mr. Fowler at Fundium, West Africa, was one which had been in constant service at South Kensington for stellar spectroscopic work. It consists of a single prism of 45° refracting angle, supported at the position of minimum deviation in front of a photographic objective of 6 inches aperture and 7 feet 6 inches focal length. The correction of the object-glass, which is by the Brothers Henry, is such that the whole spectrum is in focus when the plane of the plate is normal to the axis of the camera. With the dispersion of the single prism the spectrum is about two inches long from H to K. The rings corresponding to the inner corona have a diameter of about seven-eighths of an inch. The objective and prism were mounted at the end of a strong mahogany tube of square section, which was attached to the declination axis of a 6-inch Cooke refractor. The plate holders were divided into three compartments, each taking a plate 4 by 6 inches. Between each exposure the slide was pushed forward so as to bring a fresh plate into position. The exposures were made by covering and uncovering the prism with a piece of thick card. During the eclipse thirty photographs were taken, with exposures ranging from "instantaneous" to 40 seconds. Six of these were made before and nine after totality.

At the Brazilian station Mr. Shackleton employed a prismatic camera consisting of a large photographic spectroscope deprived of its collimator, mounted on an iron table, in conjunction with a 12-inch siderostat. The optical train consisted of two 60° prisms of 3 inches aperture, and a Dallmeyer portrait lens of 3.25 inches aperture and 19 inches focal length. With this camera the length of the spectrum was 1.65 inches from $H\beta$ to K and the diameter of the Sun's image 0.176 inch. Each of the plate holders, of which three were provided, contained eight compartments for plates. These were successively brought into position by means of a rack and pinion. Twenty-four exposures were made, ranging in length from "instantaneous" to 60 seconds. Of these one was made before totality, and six after the end of the total phase.

The appearance of the photographs obtained in Africa is illustrated by the accompanying cut, reproduced from a positive on glass of one

of the photographs which was kindly presented to the reviewer by Mr. Fowler. It is seen that the chromosphere and prominences are remarkably well shown in a large number of rings. Of these, by far the brightest are those due to H and K, while the hydrogen rings are second to these in intensity.

In the photographs taken about mid-eclipse, some of which are reproduced in Professor Lockyer's memoir, the spectrum of the chro-

mosphere is not shown on account of the central position of the Moon. Such prominences as were high enough to be seen beyond the Moon's limb are represented in the photographs. One of the negatives faintly outlined a bright group of prominences in the *Hα* line, although the plates were not very sensitive in this part of the spectrum. Images of the prominences in D_3 were also shown. The spectrum of the corona appears from these negatives to be largely continuous, but some of the photographs show a nearly complete ring corresponding to 1474, and small portions of very faint rings. The continuous spectrum is brightest near the photosphere and fades out very gradually away from the limb. Little can be determined from these photographs regarding the wavelength of the point of greatest intensity, without a careful study of the curves of sensitiveness of the plates employed. On the ordinary plates, the position of maximum intensity is about λ 450, while on the isochromatic plates there is another maximum about λ 560. At these points the continuous spectrum extends farthest from the photosphere, on three of the plates reaching a distance of about two-thirds of the Sun's diameter.

The 1474 ring is shown in four photographs, one of them made on ordinary and three on isochromatic plates. This ring reaches its greatest height some 45″ above the Moon's limb, on a plate made about the middle of totality with an exposure of 40 seconds. The variation of the intensity of the ring is very marked, as it is clearly visible near the poles and quite bright in the equatorial regions. The position of

greatest brightness corresponds closely with the brightest regions in the direct photographs of the corona. The ring seems to have no connection with those due to the prominences, and there was no trace of the 1474 line in the spectrum of any of the prominences The memoir does not state that the 1474 ring showed any trace of structure corresponding to the rays and streamers shown in the direct photographs of the corona.

In addition to 1474 several fainter coronal rings are shown, which can be easily distinguished from the rings due to the chromosphere and prominences, as their points of maximum luminosity never coincide. Moreover, the chromosphere rings are sharply defined, while those due to the corona are hazy and indistinct. The intensities of these rings fall off rapidly in going outward from the Sun's limb. On account of the short focal length of the object-glass used in Brazil, the images of the coronal rings obtained with it are much brighter than those photographed in Africa. The Brazilian negatives taken about the middle of totality give the 1474 ring with great intensity and sharply defined outline. A comparison of this ring with Professor Schaeberle's photographs of the inner corona shows that the brightest parts of the ring correspond with the brightest parts of the corona, where the continuous spectrum is most intense.

The reviewer has previously had occasion to refer to these same photographs in discussing the nature of the so-called "white prominences."[1] They admirably illustrate the differences in the intensities of lines in the spectra of various prominences. In certain cases prominences are shown in the H and K lines which are either extremely feeble or altogether lacking in the hydrogen lines. Thus we have certain proof that prominences exist, which when seen with the naked eye would have rather a lilac than a red color. As has been pointed out in the paper just referred to, the "white prominences" observed by Tacchini and others can probably be explained in this way.

In Part II, which consists of a discussion of the observations, Professor Lockyer first considers the relative advantages of the slit and slitless spectroscopes for eclipse work. With the former, lines lying close together are less likely to be confused through overlapping of the images, feeble lines have a better chance of being recorded, and the dark lines due to reflected sunlight in the corona can be shown. The prismatic camera, on the other hand, gives results which are at the

[1] This JOURNAL, **3**, 374, 1896.

same time pictures of the various phenomena and images of their spectra. The prominences are shown in their proper positions, and their radiations are not confused with those of the corona. The light of the prominences and corona, scattered by our own atmosphere, instead of producing false lines in the spectrum, as in the case of the slit spectroscope, is practically eliminated by the prismatic camera. Further, as is also the case with stellar spectra, there is a considerable saving of light due to the absence of the slit and lenses used with the slit spectroscope. As the results recently obtained by Mr. Shackleton best illustrate, the prismatic camera is admirably adapted for photographing the "flash" at the beginning or end of totality. If the slit spectroscope were used for this purpose, the adjustments would have to be made with extreme care in order to obtain similar results, while with the slitless instrument no special adjustments are required.

The coronal rings photographed with the prismatic camera, with the exception of that belonging to 1474, are very feeble, and their wave-lengths cannot be very accurately determined. On the African photographs eight rings of this kind were found. These correspond in a general way with lines photographed by Dr. Schuster with the slit spectroscope in 1886. Many other lines have been photographed in the corona, but while some of these are probably genuine, others are undoubtedly due to atmospheric glare. On account of the uncertainty regarding the wave-lengths of the corona lines, Professor Lockyer has not hitherto been able to determine whether they are represented by dark lines in the solar spectrum. He remarks, however, that if present at all, they are among the feeble lines.

Some stress is laid on the apparent absence of the 1474 ring from the spectra of the chromosphere and prominences. Professor Lockyer concludes that when 1474 is seen at the Sun's limb without an eclipse, the spectrum of the corona itself is really observed and not that of the chromosphere. In support of this he states that he is not aware of any observation of the *form* of the prominences in 1474 light. It is true that such observations are very uncommon, but a case of this kind has been described by Fenyi[1] in a brilliant eruptive prominence observed in the vicinity of the great spot-group of February 1892, when it was at the limb. The form of the base could be distinctly seen in the 1474 line up to a height of 33″. Again, 1474 appears in the solar spectrum as a dark line, and there seems to be no good

[1] *A. and A.*, 11, 432, 1892.

reason to suppose that it does not belong to the spectrum of the chromosphere, where it is always visible.

At this eclipse, as at all others where the prismatic camera has been used, H and K were not recorded as rings in the coronal spectrum. They have frequently been photographed across the corona with slit spectroscopes, but it is now generally believed that this was due to scattering of the light of the chromosphere and prominences in our own atmosphere. It can now in all probability be considered as definitely established that the H and K lines do not properly belong to the coronal spectrum. Dr. Schuster reached this same conclusion in 1886.

As has already been remarked, the photographs show a strong continuous spectrum due to the corona. Professor Lockyer is inclined to consider that this is not truly a continuous spectrum, but rather one filled with maxima and minima of brightness, producing a ribbed appearance. This conclusion is, of course, not based upon the results obtained with the prismatic camera, but rather upon a hasty observation of his own in 1882. Until this observation has been confirmed the spectrum will probably be considered to be continuous.

In his discussion of the variability of the spectrum of the corona, it cannot be said that Professor Lockyer reaches any very certain conclusions. In 1871 the 1474 ring appeared to him very bright, but in 1878 he did not see it at all. It was, however, seen as a faint line by Professor Eastman. It was also seen in 1882, 1883 and 1893 near times of Sun-spot maxima, and in 1889 by Professor Keeler near a minimum. While the observations seem to show that its brilliancy was rather less at eclipses which occurred near the Sun-spot minimum, it can hardly be said that a periodic variation in brightness can be considered as established, especially when it is remembered that the 1474 ring photographed in 1896 was quite as strong as that photographed in 1893.

Experiments made by Mr. Fowler with the prismatic camera have shown that under certain conditions false rings can be both seen and photographed. These results have thrown some doubt upon the origin of rings which have been ascribed to hydrogen, though it would appear that in one or two eclipses hydrogen was probably present in the inner corona.

The wave-length tables which conclude the memoir contain about 250 lines. All lines seen on any of the negatives are recorded, whether

they belong to the spectrum of the chromosphere or prominences. Many of these lines have previously been observed in full sunlight or at previous eclipses, but a large number are new. The intensities are recorded on a scale of 10, the strongest line in each negative, irrespective of exposure, being given this maximum value. The great majority of lines are shown to increase in intensity as they approach the photosphere, but great stress is laid on the fact that a few lines seem to gain in brightness in passing out from the limb. It should be remarked, however, that results of this character, which are directly opposed to those ordinarily obtained in daily observations of the spectrum of the chromosphere and prominences, should be received with great caution. It is of course well known that prominences are not infrequently brighter at the top than at the bottom, so that the lines in their spectra have their maximum brightness at some distance from the Sun's limb. But this depends upon local peculiarities of structure, and can hardly be considered to have any relation to hypothetical "layers" in the solar atmosphere. In general, lines in the spectrum of prominences are brightest near the base, and brighter still in the chromosphere. Professor Lockyer bases his conclusion that the "prominences must be fed from the outer parts of the solar atmosphere" in part on the fact that the spectrum of a very bright metallic prominence shows lines which are absent from the spectrum of the chromosphere, not immediately beneath the prominence, but some distance away. The reason given for making such a comparison is that "it is fair to consider the base of the chromosphere homogeneous" (p. 607). Those who have been accustomed to observe the spectrum of the Sun's limb below eruptive prominences will not be likely to agree in this opinion.

The results obtained by Mr. Shackleton at the 1896 eclipse render unnecessary a discussion of the bearing of the 1893 results on the question of the "reversing layer." The photograph of the "flash" spectrum, which has been exhibited by Professor Lockyer to the Royal Society, will soon be reproduced in this JOURNAL. It is stated by a well-known writer in the London *Times* that there can no longer be any doubt regarding the existence of the stratum whose spectrum was first observed by Professor Young in 1870. G. E. H.

Recent Publications.

A LIST of the titles of recent publications on astrophysical and allied subjects will be printed in each number of the ASTROPHYSICAL JOURNAL. In order that these bibliographies may be as complete as possible, authors are requested to send copies of their papers to both Editors. For convenience of reference, the titles are classified in thirteen sections.

1. THE SUN.

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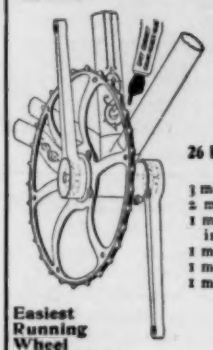

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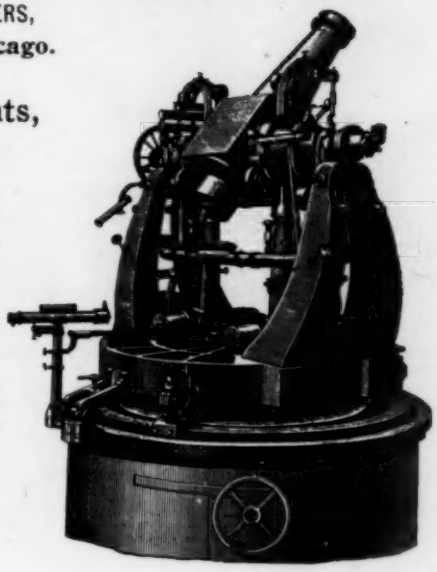

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